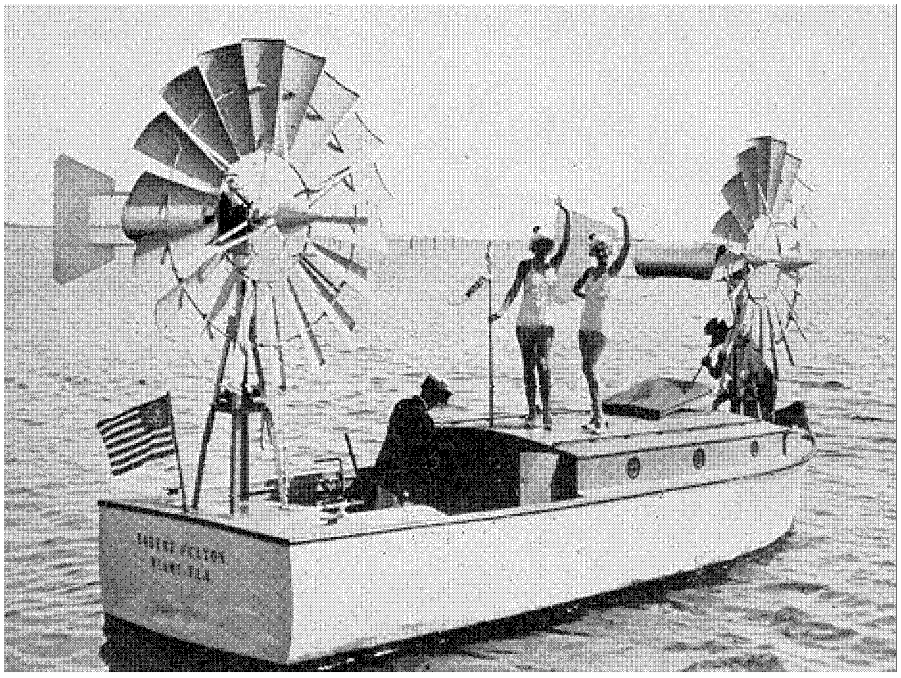
REGENERATIVE AIR CAR DESIGNS



REGENERATIVE AIR CAR DESIGNS

CONTENTS

Cover: Boat powered by wind turbines (photo only)

Inside cover: Charles Hunt's regenerative shock absorber air motor

1. Recovery of Compression Heat 1
2. Regenerative Braking..... 16
3. Regenerative Shock Absorbers..... 37
4. Neutralizing Wind Resistance 76

Pneumatic Handbook, 6th ed., R. H. Warring, Houston: Gulf Pulishing Co., 1982, p. 50

Cost Effectiveness

IN TERMS of specific energy requirement the cost of compressed air is somewhat higher than that of electricity. However, taken in isolation, direct costs of energy are only part of the overall question of cost-effectiveness, which must cover utilization (compressed air systems being suitable for some jobs where electricity is not; or in direct competition with electric motors in other cases, for example); capital costs and depreciation; overall efficiency; reliability; and operating costs (maintenance and labour). Cost-effectiveness aims at optimizing all parameters; and more particularly instituting savings when possible.

It is, for example, possible to achieve near 100% overall efficiency with a compressed air installation. This can be done by recovery of the compression heat generated in the production of compressed air.

E.M. Talbott. Compressed Air Systems: A Guidebook on Energy and Cost Savings. Atlanta: Fairmont Press, 1986. 77-79.

4.1.5 Heat Recovery

Adiabatic compression of air to 100 psi results in outlet air temperatures of 350 - 500°F. When this air is cooled to ambient temperatures, 60 - 90 percent of the energy of compression is removed, and this can be used for other purposes. This heat is a low grade source that is available year round whenever the plant is in operation. Typical uses of the air include supplemental space heating, boiler makeup water preheating, or process heating.

If a regular all season use of this low grade heat source is available, the heat recovery system efficiency considerations are of greater importance than the compressor efficiencies discussed in section 4.1. Since nearly 80% of the input energy is available as heat, the 20% energy content of the compressed air is nearly a by-product. In multiple compressor systems, the compressors could be located near each of the locations requiring space heating to minimize the ducting requirements, air pressure control stability considerations permitting.

2 FOR MORE INFORMATION ON
WET COMPRESSED AIR, SEND EMAIL TO:
ESBuck@aol.com

US005832728A

United States Patent [19]

Buck

[11] Patent Number: 5,832,728

[45] Date of Patent: Nov. 10, 1998

[54] **PROCESS FOR TRANSMITTING AND STORING ENERGY**

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[51] **Int. Cl.**[6] **F16D 31/02**

[52] **U.S. Cl.** **60/407**; 60/456; 60/649; 60/653; 60/659; 60/674

[58] **Field of Search** 60/659, 649, 673, 60/674, 650, 684, 653, 456, 407, 410

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,967,466 7/1976 Edwards 62/402

Primary Examiner—Edward K. Look
Assistant Examiner—Bijan N. Karimi
Attorney, Agent, or Firm—Joseph G. Nauman

[57] **ABSTRACT**

A process for transmitting or storing energy in which a gasseous working fluid is compressed and cooled, relative to isentropic compression, by a coolant. The energy used to perform the compression is recovered by expansion, while heat from the coolant is used to reheat the working fluid, thus maximizing efficiency.

8 Claims, 4 Drawing Sheets

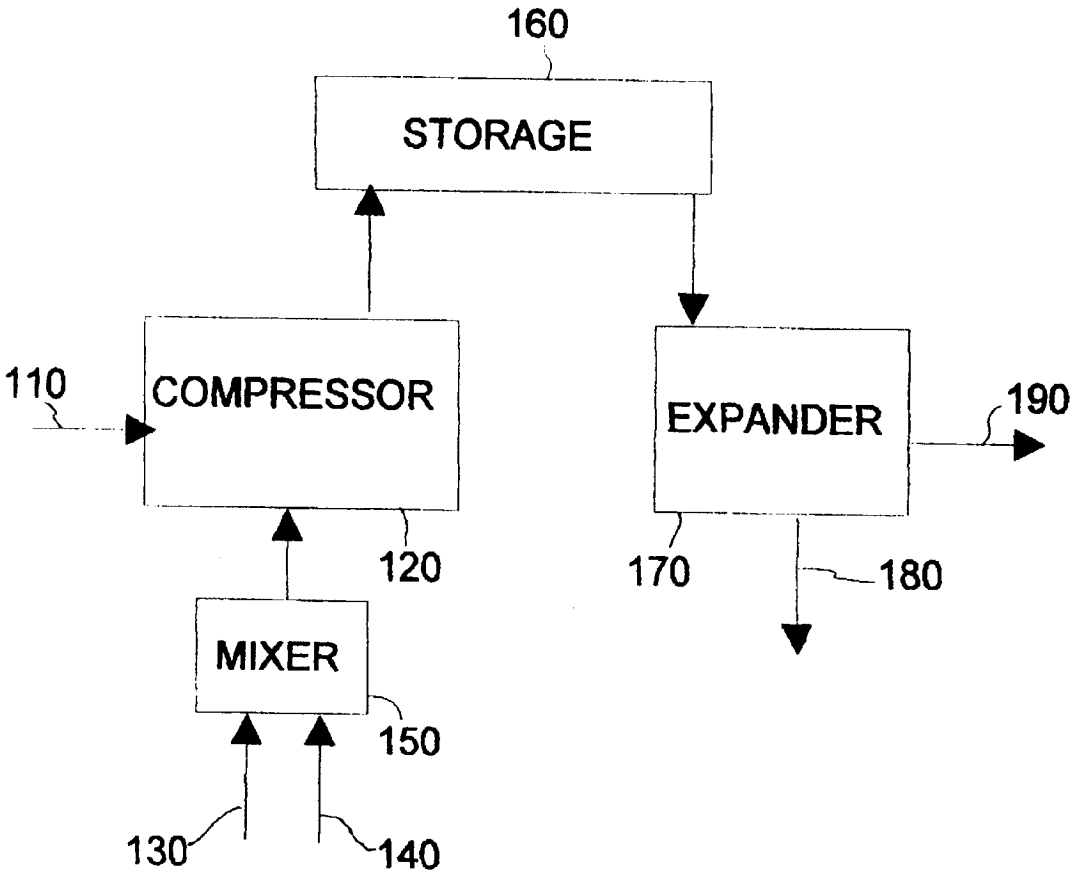


FIG. 1

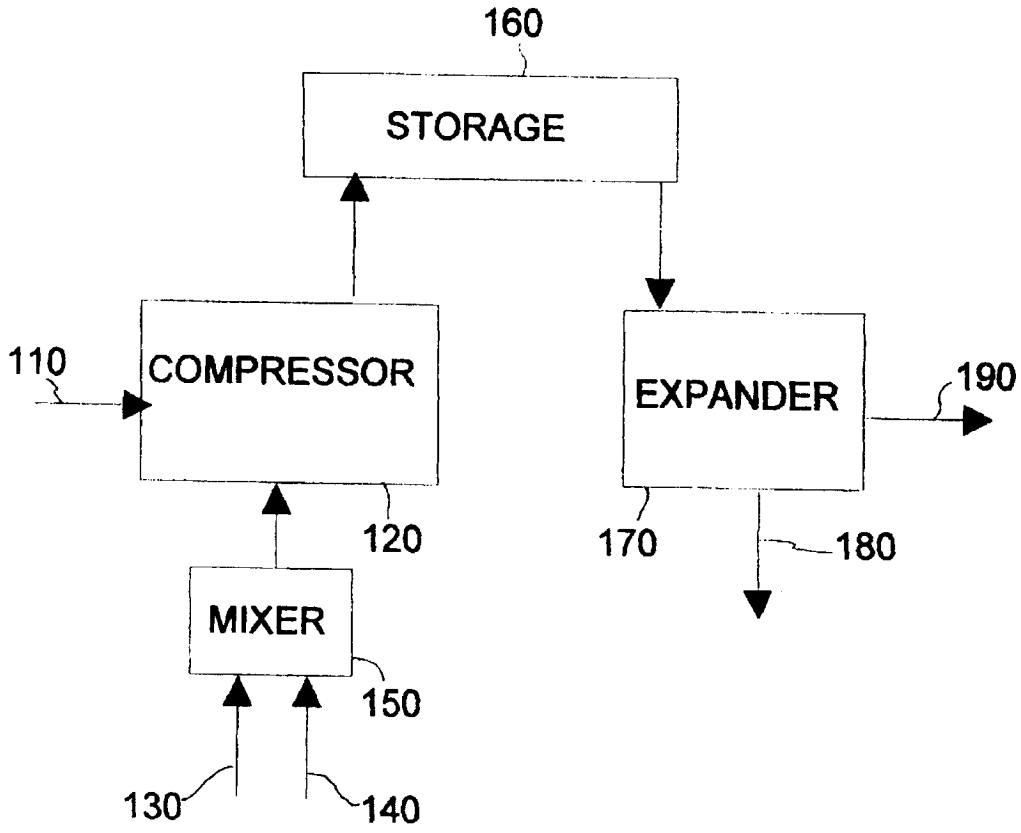

160
STORAGE
110
COMPRESSOR
EXPANDER
190
120
170
180
MIXER
150
130
140

FIG.2

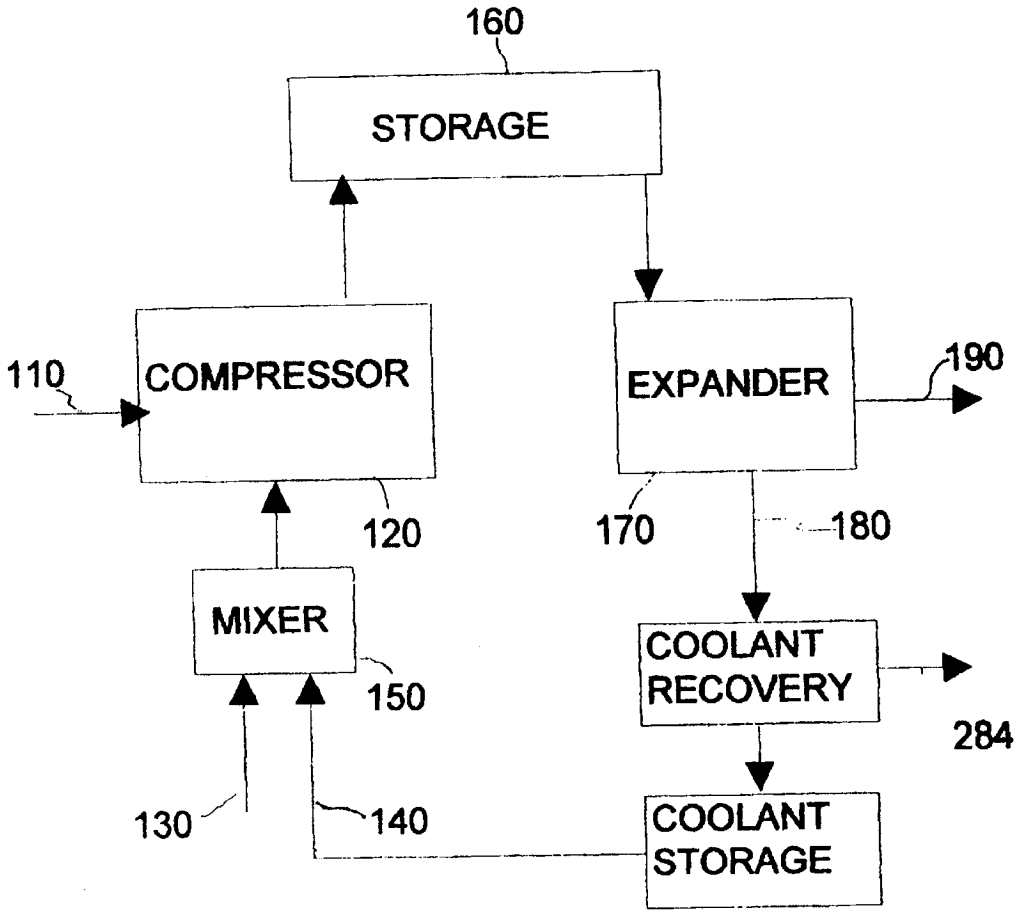

160
STORAGE
110
COMPRESSOR
EXPANDER
190
120
170
180
MIXER
150
COOLANT RECOVERY
284
130
140
COOLANT STORAGE

FIG.3

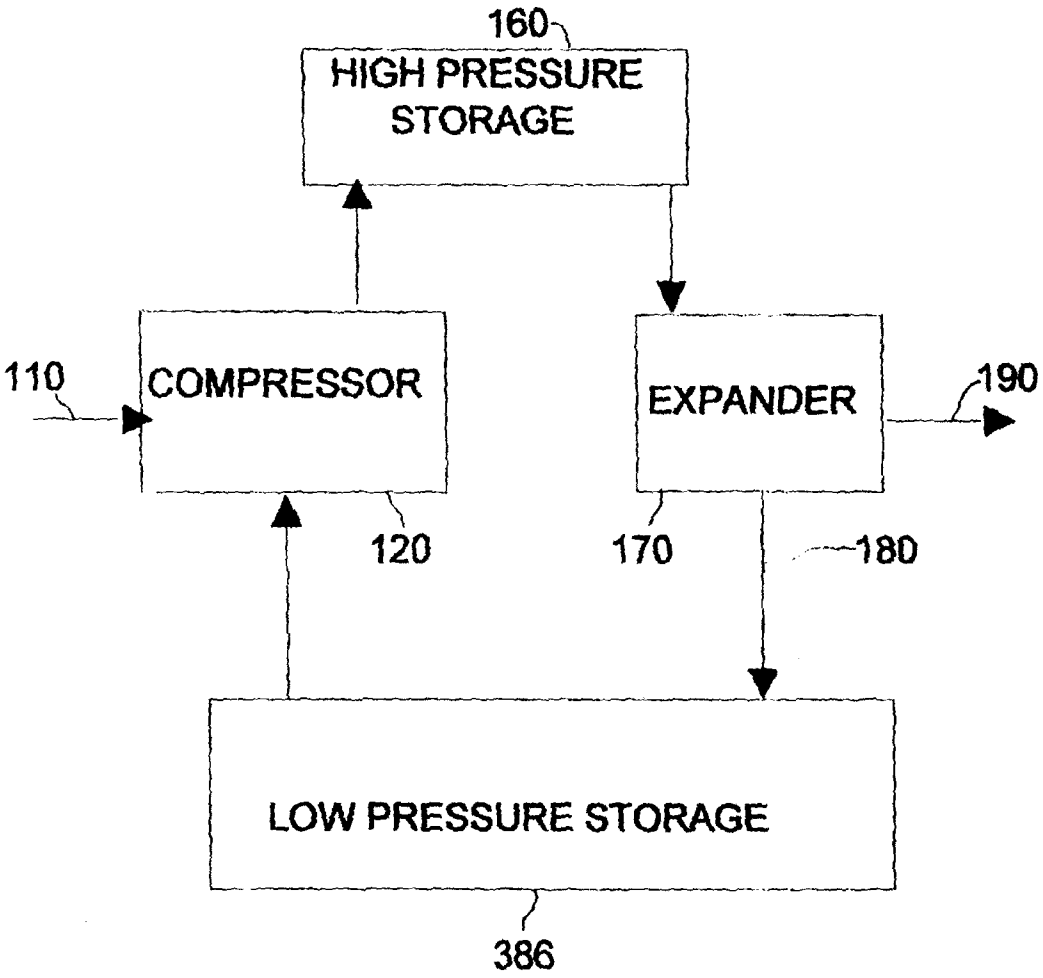
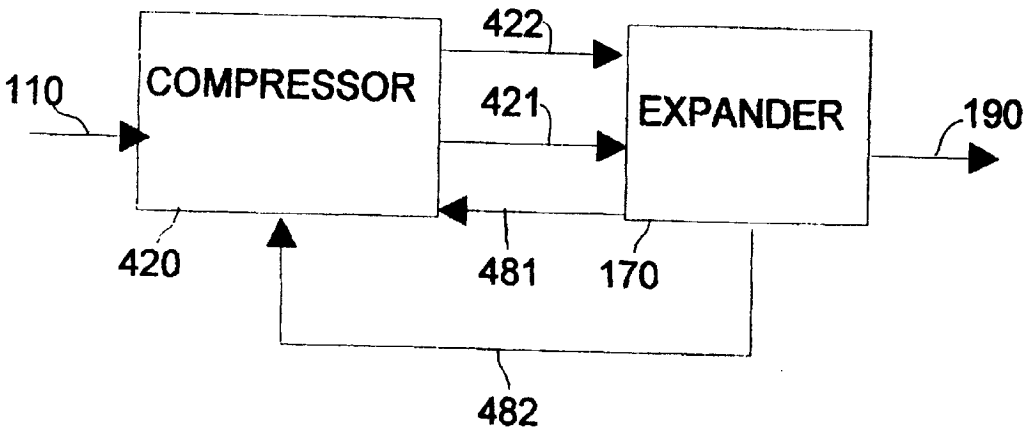

160
HIGH PRESSURE STORAGE
110
COMPRESSOR
EXPANDER
190
120
170
180
LOW PRESSURE STORAGE
386

FIG. 4



PROCESS FOR TRANSMITTING AND STORING ENERGY

BACKGROUND—FIELD OF THE INVENTION

This invention consists of an improved method (process) of energy storage, whether fleetingly, as in power transmission from one point to another, or more lastingly, as in load leveling for utilities, for storing solar or wind energy for dark or calm periods, or for powering "zero emissions" vehicles.

BACKGROUND OF THE INVENTION

Existing energy storage processes, especially those applicable to powering mandated "zero emissions" vehicles, are few. Flywheels are hardly "existing" technology. Electrochemical storage batteries have disadvantages and will be discussed later. Systems depending on gravity only work when going downhill. Obvious, but not fashionable, alternatives to batteries are compressed gasses, air or steam, as a storage medium for energy. For purposes of illustration, these processes will be described in the context of a "zero emissions" vehicle, as mandated by law in some places.

Both steam and compressed air have been used for well over a century. Fireless railroad locomotives, refilled with steam from a stationary boiler, could shunt cars for half a day between refills. Compressed air is still widely used as an energy storage medium, from air rifles to heavy mining equipment, even for utility load leveling in a few cases. At least one compressed air car is in use in Joplin, Mo.

There are two measures of merit which apply. One is the amount of useful energy which can be stored in a given volume, energy density. Higher is better; it affects the "unrefuelled range" of a zero-emissions car. The other measure of merit is thermodynamic efficiency, which affects the cost of operation. Higher efficiency, lower cost, is better. None of the existing vehicles powered by air or steam is efficient; they waste energy. Either compressed air or steam involves losing heat from the system, hence lower efficiency, higher costs. However, to make this clear, there follows a comparison of three energy storage processes, as might be applied to a zero emissions vehicle.

For illustative purposes, keeping the engineering challenges within the state of the art, assume that temperatures may not exceed 600K, a value chosen as metallurgically acceptable. Environmental effects must also be considered. Exhaust temperatures are limited, as a lower bound, to 200K, which is still frighteningly cold. Common lubricants thicken at such temperatures. Human contact with such exhaust would result in frostbite, and, as the cold exhaust mixed with ambient air, fog and/or snow would result. The same size storage tank is assumed for each system, conveniently 1000 L, 1 m^3. Such tankage would fit behind the seat of a small car, or under the bed of a pick-up truck. A specially built vehicle could accomodate more tankage.

The following calculations make certain assumptions as listed. Purists will argue that they are imprecise, but they are adequate to compare systems.

1. Air is an ideal gas. k=1.4; PV=RT, where R for air is 0.28 KJ/(kg-K) or 2.8 L-bar/(kg-K) ; for isentropic processes, $T_2/T_1=(V_1/V_2)^{k-1}$; $P_2/P_1=(V_1/V_2)^k$; Work at 100% eff. is $(U_1-U_2)=\text{mass}(C_v)(T_1-T_2)$. C_v=0.75 kJ/kg-K (It is not constant, but let's assume it is) The work done to compress the air isothermally (impossible in practice, but assumed here) is $P_1V_1\ \ln(V_2/V_1)$. Ambient air, the intake to the compressor, is at 300K, 1 bar pressure, with a density of 1.18 g/liter. Exhaust pressure cannot be below 1 bar.

2. Steam behaves as listed in steam tables.

3. Efficient expanders (motors) with variable expansion ratio and no internal friction are available. (Zero friction is impossible, but assuming it treats all the systems equally with regard to friction losses)

4. Another assumption, which can be questioned, is that all the stored gas is useable. Clearly, as the pressure drops, the expansion ratio of the motor must decrease, but assuming a variable expansion ratio (which may be achieved with valve timing) for comparison purposes, there is no big error involved in calculating energy density or efficiency. Batteries, of course, cannot be totally discharged, either.

Process A: Energy storage with dry compressed air.

The Pneumocon Inc. car, "Spirit of Joplin", now running in Joplin, Mo., uses air stored at 3000 psi (about 200 bar) and ambient temperature, about 300K. The output is throttled, to reduce pressure to 33 Bar, still at approximately 300K, but if expansion is limited by the temperature of the exhaust the power output and efficiency remain essentially unchanged over a broad range of pressures. A thousand liters of air at 200 bar would weigh 236 kg. The energy output, ideally, would be (236 kg.) (0.75 kJ/kg-K) (300K-200K)=17.7 megajoules (4.9 kw-hr). The work required to compress the air isothermally would be $P_1V_1\ \ln(V_2/V_1)=(10^5\ N/m^2)$ (200 m^3) (−5.52)=110 megaJoules. Efficiency, useful output divided by energy input, is 17.7/110 or 16 per cent. (Typical industrial compressed air systems rarely exceed 15 percent overall efficiency)

Suppose, in an effort to improve energy storage density, the pressure is increased to 600 bar, which is acheivable with available components. The amount of air stored will triple, as will the weight of the tanks, approximately, as the walls will be thicker. Now the output will be tripled, to 53 megaJoules, 14.7 kw-hr, and the input will be 384 megaJoules. Efficiency would drop to 14 percent. Since the energy density increase is large for a small drop in efficiency, high pressures seem desireable.

Process B: Storing compressed air at 600K.

A multistage compressor would compress the air until it reaches 600K, the maximum temperature allowed, then compress it isothermally until the pressure reaches 200 Bar. The tank will hold only 118 kg of air at that temperature. The first compression adds energy to the air (isentropically), 0.75 kJ/K or 225 KJ/kg, which is 26.6 megaJ total for the first stage. The pressure is 11.7 bar and the volume 17 m^3. The isothermal compression to 1 m^3 and 200 Bar consumes 56.3 megaJ, for a total of 82.9 megaJ. When the air is expanded with a temperature drop of 400K, the energy recovered is 35.4 megaJ, 9.8 kw-hr, with an efficiency of 43 percent. During the isothermal compression, about 56 megajoules of heat is rejected (since the internal energy, U, of the compressed air was not increased).

Suppose we prefer to store the air at 450 bar. We can store 265 kg of air, 22 kw-hr, but the energy to isothermally compress the air has risen to 163 megaJ, 189 MJ total input, for an output of 79.6 MJ, or an efficiency of about 42 percent. Again, higher pressures seem better. Since tanks are likely to be stronger at 300K than at 600K, the 450 bar and 600K process and the 600 bar at 300K process are likely to be comparable in weight. It would seem Process B is superior, with higher efficiency and higher energy density.

Process C: Energy storage in steam.

The greatest energy density occurs when we fill the tank with saturated steam at 600K (maximum temperature allowed). The pressure is about 125 bar, specific volume is 13.5 L/kg, U=2500J/kg, entropy=5.47. The mass of steam in the 1000 L is about 74 kg. Total internal energy, U, is 185

megaJoules. Since we started with 74kg. of liquid water at 300K, which had an internal energy of 8 megaJoules, the work required to fill the tank with steam was approximately 178 megaJoules or 49 kw-hr.

Now, we need to know how much mechanical energy we can extract from that steam. The perfect expansion process is isentropic; total entropy remains the same. However, we know that as the steam does work it will cool, and some will condense. (Steam is not an ideal gas) At 1 Bar (exhaust), we will have X kg of steam and (74-X)kg. of water, both at about 373K. Water at that temperature has entropy=1.30 and steam has 7.35. X(7.35)+(74-X)(1.30)=74(5.47) It follows, after a bit of elementary algebra, that the exhaust had 51 kg of steam and 23 kg of water. The total internal energy of the exhaust is 51 kg(2506 kJ/kg)+23 kg(419kJ/kg)=137.4 megaJoules. Subtracting that from the initial enegy, we find that the greatest possible mechanical work we could get from the steam system is 40.6 megaJoules or 11.3 kw-hr., and the efficiency is only 23 percent. The exhaust is dangerously hot, and it cannot be exhausted directly from a vehicle without creating fog and raining on the following vehicles; a big condenser is needed.

Summary of characteristics of the three ideal processes:

	useful output	efficiency	fuel cost
A: 300K compressed air	14.7 kw-hr	14%	7
B: 600K compressed air	22 kw-hr	42%	2.4
C: 600K steam	11.3 Kw-hr	23%	4

Arguably, any of these state-of-the art processes is competitive with electrochemical batteries. A battery powered car typically stores about 20 kw-hr of energy; when that is exhausted, it takes hours to recharge the batteries. Power output is limited to approximately 200 W per kilogram of battery, so the power to weight ratio is poor. Compressed gas vehicles can release stored energy at much higher rates and can be recharged from a stationary "filling station" in minutes.

Relatively inexpensive and non-toxic materials are used (mainly ferrous metal technology) in the three systems described, and there is little to wear out; no expensive batteries are used which need periodic replacement/recycling. (The cost of recycling the batteries periodically overwhelms the cost of electricity) The impracticality of electric cars is nicely described in the February 1995 issue of *Popular Science* in an article titled, "It's The Battery, Stupid!" A December 1994 report, "Electric Vehicles", by the U.S. General Accounting Office, concludes, "The ultimate viability of EVS as a widespread tranportation option cannot now be ensured." Economics favor compressed gasses over electrics, both in low operating cost (no recycled batteries) and in first cost; an electric van from Chrysler is priced at $120,000, while an air-powered vehicle need not be substantially more expensive than current vehicles; it is mechanically simple (eg. simple or no transmission, no radiator, no ignition system, no catalytic converter, etc.).

Most of the disadvantages of batteries in vehicles also apply to stationary storage schemes. Telephone companies use a lot of batteries, now, but it is hard to imagine a public electric utility load-levelling with batteries. However, large storage tanks at elevated temperatures appear to be feasible, perhaps underground or under water or in remote locations, to allay public fears of an explosion and to minimize real estate costs.

Parenthetically, hydrogen-air fuel cells might compete as sources of power for vehicles, but there will be "consumer resistance" to hydrogen in cars. Will they be allowed in tunnels? A fuel-cell powerplant in New York City was vetoed by the city fire department.

SUMMARY OF THE INVENTION

This invention discloses a process of storing and transmitting/converting energy by (a) compressing a working fluid, (b) adding a coolant fluid during the compressing operation and (c) storing the mixed working and cooling fluids in a pressure vessel, and then (d) expanding the stored mixture as through a fluid motor to extract energy from the compressed mixture. In addition, a further step of (e) condensing and returning coolant fluid may also be utilized.

Accordingly, several objects and advantages of my invention are:

(a) To provide an energy storage process which is more efficient than present methods of energy transmission and energy storage. (b) To provide a way to achieve high-density energy storage.

(c) To provide a process which can be scaled for large applications (utilities) or small (portable tools).

(d) To provide a power transmission process (eg. from engine to multiple powered wheels or fork lift) which is simpler and more convenient than commonly used means, such as shafting or conventional hydraulics.

(e) To provide an energy storage process which requires no breakthroughs, uses non-toxic materials and well understood mechanisms.

(f) To provide a means of energy storage which can be charged and discharged at very high rates.

(g) To provide a process which, considering capital and replacement costs, is more economical than existing methods of energy storage, such as batteries.

(h) To provide for the use of high-pressure gasses without the high temperatures associated with high-pressure gasses compressed isentropically and without the wasted heat energy associated with isothermal compression.

(i) To provide a process which facilitates heating and cooling.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a flow chart of the essential process.

FIG. **2** shows the addition of recycling a coolant.

FIG. **3** shows a closed-cycle process in which the mixed working fluid and coolant are reused—useful for power transmission.

FIG. **4** shows a modification of the process of FIG. **3**, in which the coolant and working fluid are kept from mixing.

REFERENCE NUMERALS IN DRAWINGS

Comparable elements of each process bear the same number in each applicable figure. Not shown are valves and controls, coolant pumps, etc., which are obvious to anyone skilled in the art.

110: Energy input (eg. a turning shaft)

120: One or more compressors

130: Working fluid input to mixer.

140: Coolant input to mixer.

150: Mixer

160: Storage tank or tanks, insulated, as desired.

170: Expander (eg. motor or pneumatic cylinder)

180: Exhaust from expander.

190: Energy output from expander.

282: A device for removing coolant droplets from the working fluid.

284: Dry working fluid is exhausted.

286: Storage tank(s) for recovered coolant.

386: Storage container(s) for mixture of low-pressure working fluid and coolant.

420: Compressor(s) cooled by coolant.

421: Conduit for dry working fluid to expander(s).

422: Conduit for coolant to expander(s).

481: Conduit for low-pressure working fluid, returned to compressor(s).

482: Conduit for coolant, returned to compressor(s)

The invention consists of a process in which mechanical energy is expended to compress gasses and said energy is recovered by passing the gasses through an expander (motor) to provide mechanical energy again. The novelty lies in the use of two fluids, a fluid with a high heat capacity to cool the compressor(s) and a second, working, fluid. The cooling fluid may undergo a phase change from liquid to gas, absorbing "latent heat of vaporization", which keeps the temperature of the combined compressed gasses lower than would be the case if isentropic compression of the working fluid were involved. The key point is that the heat absorbed by the cooling fluid is not wasted, as it would be with conventional (isothermal) compression. Heat from the cooling fluid is used to counteract the cooling which results from the expansion of the working fluid as it drives the motor, resulting in a process which is thermodynamically reversible, ideally efficient, in contrast to existing fluid power systems. (This is not to be confused with humidified compressed air, the CASH cycle)

FIG. **1** illustrates the basic process as a flow chart. One or more compressors, **120**, are driven by energy input, **110**. A working fluid (conveniently air), **130**, is mixed with coolant fluid (conveniently water), **140**, in a suitable device, similar to devices for mixing fuel and air, **150**, and the mixture is fed to the compressor. Upon compression, the air gets hotter and the water droplets suspended in the air turn to steam, absorbing a great amount of heat which would otherwise be wasted by the necessity to cool the compressor. The mixture of air and water/steam may optionally be stored in an insulated tank or tanks, **160**, until energy is needed. To recover the energy used during compression, the mixed gasses are conducted to one or more expanders, **170**. As the gasses expand, doing work, providing an energy output, **190**, the gasseous coolant condenses, releasing heat which it previously absorbed in the compressor. The exhaust of expander(s), **180**, is close to the same temperature as the fluids fed to the compressor; hence energy lost as waste heat is minimal.

FIG. **2** illustrates a modification of the process in FIG. **1**, with enegy input, **110**, compressor(s), **120**, storage tank(s), **160**, and expander(s), **170**. In addition, the exhaust, **180**, is passed through a filter or particle separator or other means, **282**, to remove the coolant droplets from the exhaust, and the dry working fluid is exhausted, **284**. The coolant may be stored in tank(s), **286**, and reused, sent back to the mixer, **150**. This has two beneficial effects; it conserves coolant, and it prevents negative effects on the environment which might result from releasing a cloud of coolant droplets. Again, pumps, controls, valves, etc. which are obvious are omitted.

FIG. **3** illustrates a closed-cycle version of the process, with compressor(s), **120**, and expander(s), **170**. The mixed working fluid and coolant, **180**, are directly recycled, with (optionally) storage tanks, **160** and **386**, to accomodate variations in flow. This process may be preferred for simply transmitting energy from one place to another, but the storage capacity will be limited because the low-pressure working fluid exhausted from the expander(s) will consume an inconveniently large volume and the coolant droplets may not remain suspended in the working fluid.

FIG. **4** illustrates a process in which the working fluid and the coolant are not mixed but are kept physically separate, with conductive heat transfer cooling the working fluid at the compressorts) and heating the working fluid at the expander(s). The compressor(s), **420**, are different from **120** in that they are cooled by circulating coolant (in a "water jacket" or intercoolers) which is transfered by insulated conduit, **422**, to the expander(s) **470**. The compressed, dry working fluid goes to the expander(s) though a separate conduit, **421**. At the expander **470**, the working fluid is warmed by the coolant, most conveniently with heat exchangers between stages of a multi-stage expander (not required when the fluids are mixed). The separate fluids are returned to the compressor(s) through conduits, **481** and **482**. It might be advantageous to use alternative fluids in special circumstances, aboard spacecraft or submarines, for example, where the fluids (eg. helium and a liquid metal, or various organic substances) would be recycled in a closed system.

Operation

The operation of the process is illustrated by use for a zero-emissions vehicle, though the process is amenable to a variety of uses. Using the same assumptions as described under Prior Art, the superiority of my invention is obvious. It can be called "Process D." The working fluid is air, and the coolant is water, resulting in what I call "wet compressed air" (WCA).

The use of a mixture of steam and air appears to be novel and not obvious, as indicated by the lack of literature references to the practice. There are references to warming air with steam, to ameliorate the chilling effect of the exhaust of air tools in mines, but the steam was not generated by the compression of the air. Handbooks and texts on compressed air technology typically stress the desireability of removing moisture from the air, not adding it. It appears that the patent classification list has no sub-class for power plants which mix steam with air in a context which does not involve combustion; hence a search turned up no relevant patents.

Process D: Energy storage in WCA.

This process resembles Process B (in Prior Art), except that the intercooler is missing. Instead of throwing away about half the input energy, the heat of compression is used to make steam, which is conserved. Let's assume water is mixed with the air at the compressor as in FIG. **1** and FIG. **2**. As the air is compressed, the temperature increases, vaporizing the water droplets, so that a mixture of steam and air passes to the storage tanks. 118 kg of air is pumped into the tank at 600 K, with an increase of internal energy of 26.6 MJ. However, the mass of air in the tank is less (60+%), because there is now steam in the tank, also, from water boiled during the compression process. The energy used to compress the air rises to approximately 66.5 megaJoules and that energy is making about 30 kg. of steam, with the partial pressure of the air approximately 330 bar and the partial pressure of steam 125 bar, for a total pressure of 455 bar, which is feasible. (The mass of the contents is about 115 kg less than Process B at 450 bar) The total energy in the tank, at 600K, is now about 93 megaJ, the same as the input

energy, since no heat was rejected from the insulated system. Now, when the mixture is expanded, isentropically, the exhaust at 1 bar is at the original temperature, 300K, and no energy is lost in the exhaust. The steam condenses to water droplets, and the heat released as it condenses expands the air, so all the energy is recovered. The compression-boiling and expansion-condensation is a thermodynamically reversible process. The energy output is the same as the energy input, 93 MJ or about 26kw-hr. The WCA tank and motor can be in a vehicle, while the compressors and bulk storage tanks are at various filling stations, with quick-disconnect hoses to recharge the vehicle, or the vehicle can be a hybrid, with an engine and compressor in the vehicle.

Summary of characteristics of the processes:

	useful output	efficiency	fuel cost
A: 300K compressed air	14.7 kw-hr	14%	7
B: 600K compressed air	22 kw-hr	42%	2.4
C: 600K steam	11.3 Kw-hr	23%	4
D. 600K WCA	26 kw-hr	100%	1
E. Electric batteries	20 kw-hr	85%	High*

*The cost of parking at a recharge station and of replacing the batteries overwhelms the cost of the electricity.

Process D, Wet Compressed Air (WCA), is the clear winner in energy density, cost, and environmentally harmless exhaust (ambient temperature air with droplets of water which can be filtered out and recycled). It is useful over a wide range of temperatures and pressures.

Summary and Ramifications

The invention improves the efficiency of compressed-gas energy transmission/storage by factors of 2–7. The heat normally wasted by cooling the gas and compressor is retained in a coolant and returned to the gas during excpansion, approximating an ideal, reversible thermodynamic process. Therefore, the cost of compressing the gas, the fuel cost, is reduced, making the novel process economically and environmentally preferable to other processes for storing energy. It is also, generally, safer to use, as a leak will exhaust ambient temperature gasses and droplets of coolant, innocuous as compared with hot steam, cold air, or battery acid.

A few utilities store off-peak energy with caverns full of compressed air and use the compressed air to generate electricity during periods of peak usage. The invention would make this much more efficient, therefore more economical. Because the energy can now be stored efficiently, in relatively low-cost containers, a number of applications are feasible. Used in a small scale, the "Process D" could power portable tools, lawnmowers, self-launching gliders, boats, and the like, with little noise and no pollution. Inconstant sources of energy, such as wind turbines, can drive compressors, piping the "WCA" to a central storage and electric generating facility. This would eliminate the considerable difficulties of using a variable-speed turbine to generate 60 Hz. alternating current, phase matched with the power grid. Because the energy can be stored in insulated tanks, it would be more practical to use the wind turbines, tidal turbines, a space-based microwave system, solar energy, or even internal combustion engines as energy sources than is the case now; energy would be available on demand, even if the wind was calm, the tide slack, etc. Further, "WCA" can be used for space heating in its compressed form. If heat is rejected before expansion, heating something else, the exhaust will be cool and applicable to refrigeration or air conditioning.

The invention, as illustrated in "Process D", used in a zero-emissions vehicle, can surpass any existing environmentally benign vehicle in efficiency, low cost, acceleration, and fast recharging—minutes rather than hours. By way of comparison with electric cars, such cars typically store about 20 kw-hr of energy, with an overall efficiency of perhaps 85 per cent, so the "unrefuelled" range of a WCA-powered vehicle (26 kw—hr) should be at least as good as a state of the art electric vehicle. However, the WCA car can be refuelled in less than five minutes (via a quick-disconnect hose), vs. hours, and there is virtually no limitation in the rate of "discharge". (The best batteries yeild only about 200 W per kilogram, which give the electric car a poor power to weight ratio) Hence a WCA car with 1000 liters of tankage (comparable in size and weight to batteries) could outperform any electric car, winning a short race with greater speed and acceleration, winning a long race by means of shorter "pit stops". If WCA were supplied by ordinary gasoline filling stations, a WCA car could achieve the same range, the same miles per day in intercity travel, as a gasoline-powered car. Relatively inexpensive and non-toxic materials are used (mainly ferrous metal technology), and there is little to wear out; no expensive batteries which need periodic replacement/recycling. In the event of accident, no dangerous materials are released, just air and water at ambient temperature. WCA energy storage is "environmentally friendly." The recycling of automobile batteries, even now, is a great concern to EPA and OSHA; yet electric automobiles will multiply those problems a hundredfold. If electric cars are built in the millions, what will happen to the price of lead? (Nickel? Cadmium?) Who will build the new mines and smelters to meet the demand for millions of tons of toxic metal? How long will it take to get the environmental impact assessments approved? How will the millions of charging stations needed, approximately one per car, be built, and who will pay for them?

In summary, this invention, "WCA", is a novel technology with distinct advantages over existing methods of energy storage. It can be portable or stationary, with a high effective energy density. It is efficient and economical. It is non-toxic and kind to the environment. In the case of a transportation system, using WCA-powered vehicles, the rapid refill allows a vastly simpler infrasructure for "recharging" the vehicles. WCA could be dispensed at ordinary filling stations, would not requiring parking the vehicles for hours at electrical recharging stations. (Even if the electricity is cheap, a "wired" urban parking space won't be) WCA can be generated by any means capable of driving a pump: eg. off-peak electricity, wind turbines, solar Stirling engines, natural gas engines, even tidal power. It can be stored economically for long periods in insulated tanks and lends itself to large-scale energy storage. (A million kw-hr storage tank would be inexpensive compared to equivalent batteries, and would not require opening new mines and smelters to provide the toxic materials needed for batteries) Consequences of using the WCA process include the following:

1. Electric cars will become an historical curiosity, with no attractiveness to consumers, since a WCA car will cost less to buy, cost less to run, and will out-perform an electric car.

2. Considering the total system, power generation, distribution, etc., and the lesser infrastructure required to sell WCA to the public, WCA will be more efficient, less polluting, and easier to implement.

3. It will be more efficient than current load-leveling systems, used by a few utilities, which involve storage of dry

compressed air, underground. Therefore, the environmental effects and costs of large-scale energy storage will be less.

4. WCA can be applied to wind or solar systems (or even space-based microwave energy systems) to store energy and would be especially useful in places (the polar regions, islands, third world countries, mountain tops) where diesel fuel and commercial electricity are hard to get.

5. WCA can be used for heating and cooling purposes.

6. WCA can be used in "portable" applications: robots, naval torpedos, unmanned aircraft, off-road vehicles (with "free" power takeoff for fork lifts, etc.), toys, etc.

I claim:

1. A process for storing and transmitting energy comprising the steps of

a) compressing a gaseous working fluid with a compressor apparatus employing input mechanical energy, thereby creating heat energy in the working fluid and the compressor apparatus,

b) cooling the working fluid and the compressor apparatus by mixing with the working fluid a coolant fluid which absorbs heat energy from the working fluid and the compressor apparatus while mixing with and being compressed with the working fluid,

c) storing the compressed mixture of working fluid and cooling fluid in a pressure vessel, and

d) withdrawing the compressed mixture from the pressure vessel through an expander which extracts mechanical energy from the compressed mixture.

2. The process defined in claim **1**, further including the step of (e) collecting the cooling fluid from the expanded mixture and returning the collected cooling fluid to the compressor apparatus.

3. The process as defined in claim **1**, wherein the mixing of the working and cooling fluids occurs prior to the intake of fluids to the compressor apparatus.

4. The process defined in claim **1**, wherein the working fluid is air and the cooling fluid is a phase change fluid which will undergo a phase change expansion thereby absorbing heat from the working fluid and the compressor apparatus.

5. The process of claim **4**, wherein the cooling fluid is water.

6. A process for storing and converting energy comprising the steps of

a) compressing a gaseous working fluid with a compressor apparatus employing input mechanical energy, thereby converting the mechanical energy into heat erergy in the working fluid and in the structure of the compressor apparatus,

b) cooling the working fluid and the structure of the compressor apparatus during the compressing step by mixing with the working fluid a coolant fluid which absorbs as heat of vaporization some of the heat energy from the working fluid and from the structure of the compressor apparatus while being compressed with the working fluid,

c) then storing the compressed mixture of working fluid and cooling fluid to provide a depletable energy source in a transportable vessel, and

d) withdrawing the compressed mixture from the vessel through an expander to extract heat energy from the compressed mixture and to convert the heat energy to mechanical energy and also to exhaust some of the mixture at a substantially lower state of compression whereby at least some of the cooling fluid condenses to liquid form.

7. The process defined in claim **6**, including the further step of (e) collecting the condensed cooling fluid from the exhausted mixture and returning the collected cooling fluid to the compressor apparatus.

8. The process of claim **7**, including the further step (f) of collecting the expanded working fluid and returning the collected working fluid to the compressor apparatus.

* * * * *

No. 768,691. PATENTED AUG. 30, 1904.

W. R. PRATT.

AIR ENGINE.

APPLICATION FILED DEC. 28, 1901.

NO MODEL.

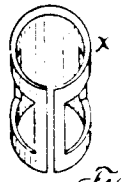


Fig. 6.

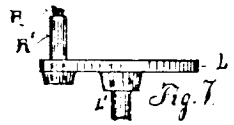


Fig. 7.

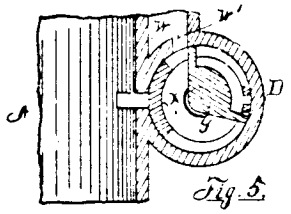


Fig. 5.

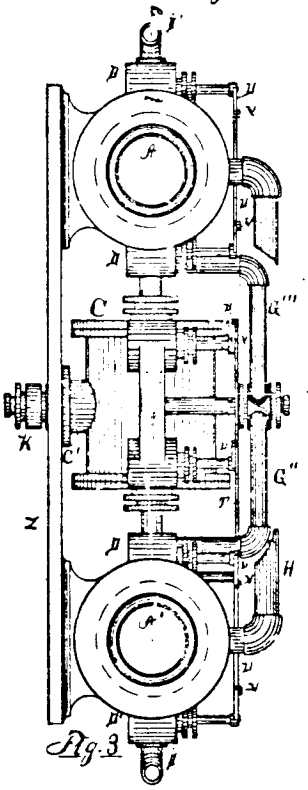


Fig. 3.

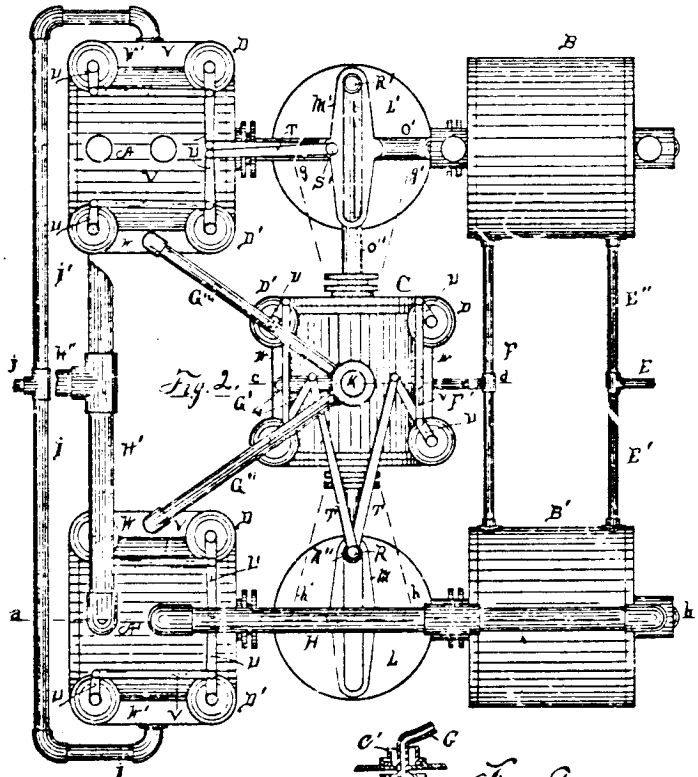


Fig. 2.

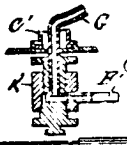


Fig. 8.

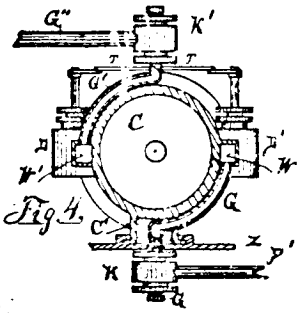


Fig. 4.

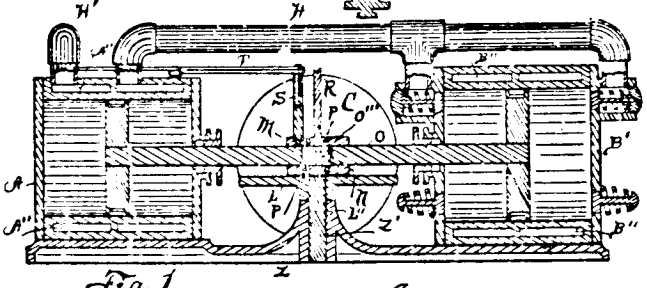


Fig. 1.

Witnesses.
M. W. Gilmore
J. H. Hunt

Inventor.
Wilson R. Pratt.
By his Attorney
F. M. Comstock

No. 768,691. Patented August 30, 1904.

UNITED STATES PATENT OFFICE.

WILSON R. PRATT, OF TOPEKA, KANSAS.

AIR-ENGINE.

SPECIFICATION forming part of Letters Patent No. 768,691, dated August 30, 1904.

Application filed December 28, 1901. Serial No. 87,603. (No model.)

To all whom it may concern:

Be it known that I, WILSON R. PRATT, a citizen of the United States, residing at Topeka, in the county of Shawnee and State of Kansas, have invented certain new and useful Improvements in Air-Engines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to the letters of reference marked thereon, which form a part of this specification.

My invention relates to air-engines wherein the fluid air stored at a high pressure is utilized during its reduction to a low pressure as initial energy for the compression of free air.

The compressors as devised are compounded, there being an oscillating primary engine receiving air at a high pressure and exhausting into two straight-line engines, the said exhaust forming initial energy for the straight-line engines—that is, engines in which their pistons travel only in a straight line. The oscillating primary engine is a portion of the mechanism constituting a toggle-joint which exerts its extreme of stress at a time when most required in the compression of free air. As the compression of air generates heat, I take advantage of this fact in so utilizing the heat units, adding them to the expanding cold air, that I get an economic result, and, vice versa, I utilize the cold produced by the expansion of compressed air in storage in reducing the heat generated by the compression of free air, to the end that the product of the compressors be greater in air at normal temperature, thus securing a secondary economy in product.

The air-compressors as devised constitute a component part of a compressed-air locomotive wherein compressed air in storage forms the initial energy.

I attain these objects by the devices and mechanism illustrated in the accompanying drawings, in which—

Figure 1 is a sectional view taken through the line *a b* of Fig. 2. Fig. 2 is an incomplete plan view showing the general arrangement of the compressors and engine, but excluding the base to which they may be attached. Fig. 3 is an end view or elevation of Fig. 2. Fig. 4 is a tranverse section taken through the line *c d* of engine C, Fig. 2. Fig. 5 is a transverse section of the valve-chest, taken through the line *e f* of Fig. 3. Fig. 6 is a perspective of the valve proper. Fig. 7 is a detail of crank-disk and crank-pin, and Fig. 8 is a detail sectional view of one of the valves. All of the views are in a measure distorted for the purposes of better illustration.

Similar letters refer to similar parts throughout the several views.

In my invention A A′ are straight-line engines, B B′ representing the air-compressors.

C is the oscillating primary engine.

As shown in Fig. 1, the engines A A′ and air-compressors B B′ have an annular open space A″ B″, respectively, formed in their castings. The engines A A′ and C have especially-designed semirotating inlet and exhaust valves, as shown at D and D′ in the several views. The valves are connected with a conduit W with ports W′, (see Fig. 5,) opening into the valve-chambers. The straight-line engines outside the valves may be of the usual construction as to cylinder-heads, piston-heads, stuffing-boxes, &c.

Outside the double cylinder no special claim is made in the construction of the air-compressors.

The novel and valuable features of my invention consist of, first, the oscillating primary engine C, which oscillates in its step C′. The piston-rod O″ of this engine is connected at one end with the crank-pin R′ of the crank-disk L′ and at its other end with the crank-pin R″ of the crank-disk L, said crank-disks rotating on the studs L″, operating in the bearing Z′ of the base Z. The rotation of the said disks is secured by the combined reciprocations of the piston-rods O, O′, and O″, the oscillations of the engine C being shown by the dotted lines *g h g′ h′*. The disk crank-pins R′ R″ play in the double-bow stirrups M N and M′ N′, and in the rotations of the crank-disks, produced, as described, by the reciprocation of the piston-rods of these engines, the ex-

treme of pressure in the air-compressors is overcome by the oscillating primary engine C by exerting the extreme of its power in forcing the crank-pins R' R'' over the toggle-joint centers g h and g' h'. The dead-centering points of the toggle-joints being passed, the straight-line engines take up their work of performing the first three-fifths of the stroke. As an antifrictional device the roller P, (see Fig. 1,) may be placed on the disk crank-pin.

In the oscillating primary engine C the valves are semirotated in the valve-chest by means of the stud R, which may be an upwardly-extending part of the crank-disk pin R'', the valve-rods T T', the valve-levers U, connecting-rods V, and valve-dogs Y. (See Fig. 5.) In the straight-line engines the studs S S' rise from the doubled-bow stirrup, as shown in Figs. 1 and 2. The studs S, S', and R move with the piston-rods of the engines and through their connections, as described, operate the valves thereof.

In operation my invention works as follows: Highly-compressed air is admitted to the conduit-pipe E by means of a suitable valve. The said air passes into the jackets of the air-compressors B' B through the pipes E' E''. The said air-compressors in compressing free air generate heat, a certain per cent. of which is taken up by the air to be used in the form of energy in the engines. After the passage of the air through the space formed by the jackets, as shown at B'', Fig. 1, it passes into the pipe F and thence into the pipe F', whence by means of the stuffing-box K it passes into the pipe G, the conduit W, and through the ports W' into the valve-chest D'. (See detail, Fig. 4.) After doing its work in the engine C the air passes through the exhaust-valve chest D and by the connecting-conduit W'' into the exhaust-pipe G', thence through the stuffing-box K' into the pipes G'' G''', which lead to the valve-chests of the straight-line engines, and operates the pistons therein, the air finally passing through the exhaust-chest of the said engines into the pipes I I' and by the pipe J into the tank of low pressure. The air compressed by the air-compressors B B' passes through the pipes H into the space A'', (see Fig. 1,) formed by jacketing the straight-line engines. As the air thus compressed carries with it a greater portion of the heat generated in its compression. it fills its function by heating the cylinders of the straight-line engines, and thereby adding heat units to the air used as energy in the said cylinders. Having fulfilled its function, as stated, it passes through the pipe H''and the pipe H'' direct to a heater, where the heat units are further increased just previous to its use in the cylinders of a locomotive.

It will thus be seen that by the aid of my invention great economy must result in the use of compressed air in storage as initial energy for it will be understood that I am able by this means not only to reduce the high pressure to a low pressure, but to use the differences of pressure in the production of compressed free air. Again, by means of the novel devices herein described I am able to add to the units of energy the greater portion of the heat units produced in compressing free air. Also in the arrangement of the air-compressors as a whole I am able, as described, to secure the greatest amount of power at a time when it is most needed.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. The combination of straight-line engines, jackets provided on said straight-line engines, air-compressors communicating with said jackets, said compressors delivering to said straight-line engines, jackets provided on said air-compressors, an oscillating primary engine adapted to exhaust into said straight-line engines, and receiving air from said last-named jackets, substantially as described.

2. The combination with an oscillating primary engine, and its piston-rod, of rotating crank-disks, crank-pins on said disks, said piston-rod being connected to the said pins, double-bow stirrups in which the said crank-pins are arranged, straight-line engines, studs arranged in said bow-stirrups and connected with the said straight-line engines, and an air-compressor connected with said stirrups, substantially as described.

3. The combination with a high-pressure oscillating air-engine, of low-pressure straight-line air-engines receiving the exhaust therefrom, compressors driven by said engines, jackets for the compressors and straight-line engines, means whereby the compressors deliver to the straight-line-engine jackets, and means for conducting the air for the oscillating engine through the compressor-jackets, substantially as described.

4. In a device of the character described, the combination of an oscillating engine, straight-line engines adapted to receive the exhaust therefrom, means for compressing air adapted to be actuated by said engines, said means provided with air-jackets, and means for conducting the air for said oscillating engine through the jacket of said compressing means, substantially as described.

5. The combination with a primary high-pressure oscillating air-engine, of low-pressure straight-line engines receiving the exhaust therefrom, air-compressors actuated by said engines, and means whereby the compressed air by which the primary engine is actuated, is raised in temperature by the heat generated in the air-compressors, substantially as described.

6. The combination with a primary high-pressure oscillating air-engine, of low-pressure straight-line engines receiving the exhaust therefrom, air-compressors actuated by

the said engines, semirotating valves arranged on the high and low pressure engines, means connected with said engines for operating said valves and means whereby the air by which the primary engine is actuated is caused to absorb heat generated in the compressors, substantially as described.

7. The combination with a high-pressure primary oscillating air-engine, of low-pressure straight-line engines receiving exhaust therefrom, jackets formed upon said last-named engines, compressors driven by said engines, jackets formed upon said compressors, means connecting said compressors with said jackets of the straight-line engines whereby the said compressors deliver thereto, means whereby the air for the oscillating engine passes through the said compressor-jackets, and means connecting said primary engine with the said straight-line engines and compressor-jackets.

In testimony whereof I affix my signature in the presence of two witnesses.

WILSON R. PRATT.

Witnesses:
W. M. CLINTOCK,
F. O. BURKET.

"Under favorable circumstances, a vehicle engine capable of developing 100 horsepower may accelerate the vehicle to 60 mph in one minute. The brakes of the vehicle, however, must be capable of stopping it in approximately one-tenth of this time, or about six seconds. The comparative horsepower then required to stop is 1000 horsepower.

"The kinetic energy developed by the weight and speed of the vehicle is converted into heat energy by the friction of the brake drum and shoe. This heat is dissipated into the surrounding air."

Irving Frazee
Automotive Fundamentals
American Technical Society
1949. Chicago

General Herman Haupt, Street Railway Motors, 1893

Increased Power from Motor Cylinders Acting as Air Pumps.

The motor cylinders are so arranged that in descending steep grades they act as air pumps, and at the same time as brakes, by which means it is found, as stated by the company's engineer, Mr. Hardie, that in running down grade on the Second Avenue Railroad, pumping back against a pressure of 200 pounds in the receiver, the pressure was increased 7 pounds in a distance of 0.4 mile. As it requires 360 cubic feet to run one mile, 0.4 mile would require 144 cubic feet.

If the pressure were increased 7 pounds in a receiver containing 160 cubic feet at 200 pounds, the air pumped back would have been 5.3 cubic feet at 200 pounds in 0.4 of a mile, equal to 69 cubic feet at atmospheric tension, which is about half the amount of air that would have been expended in running an equal distance with the aid of the heat on a level, with a consumption of one cylinder of air at each stroke, but with actual results 50 per cent. greater.

To appreciate the importance of this result, it must be observed that not only is all the air saved in running down hill and not a particle used, but half as much or more as would have been expended with the aid of heat and vapor upon a level is pumped back again, and at the same time the action of pumping back acts as a most efficient brake, the efficacy of which is spoken of by the intelligent mechanical engineer of the Delamater Works in terms of the highest commendation.

This is certainly a most extraordinary result, and so large a percentage of gain is only possible in consequence of the great expansion in the motor cylinders. The air and vapor escape at the tension of the atmosphere, without the noise which attends the escape of high-pressure steam. When the air at atmospheric tension is pumped back again, it can readily be perceived that a certain percentage of the power expended will be restored, since only half a cylinder of air or less is required to do the work at each stroke.

Such a contrivance can only be characterized as admirable, and, it will be perceived, adds another considerable percentage to gain in coal as compared with steam motors.

When a locomotive engine shall, while running, be able to manufacture coal and store it in the tender, it will then be able to rival this performance of the pneumatic motor.

It has been shown that at atmospheric tension the contents of the motor cylinder are just one cubic foot for each revolution of the car wheels and that there are 720 revolutions per mile. There should be pumped back therefore 720 cubic feet if the inclination were steep enough to employ full power, which is found by computation to be 198 feet per mile, and when heated, saturated, and expanded, this air should run the car two miles or more, instead of one. In other words, while running down hill one mile, on a grade of 198 feet, the motor theoretically might store up enough to run it two miles on a level; and recent experiments have shown that 50 per cent. may be added to this estimate.

C. R. FEAGAN.

AIR EQUIPMENT FOR AUTOMOBILES.

APPLICATION FILED APR. 4, 1919.

1,347,805.

Patented July 27, 1920.

2 SHEETS—SHEET 1.

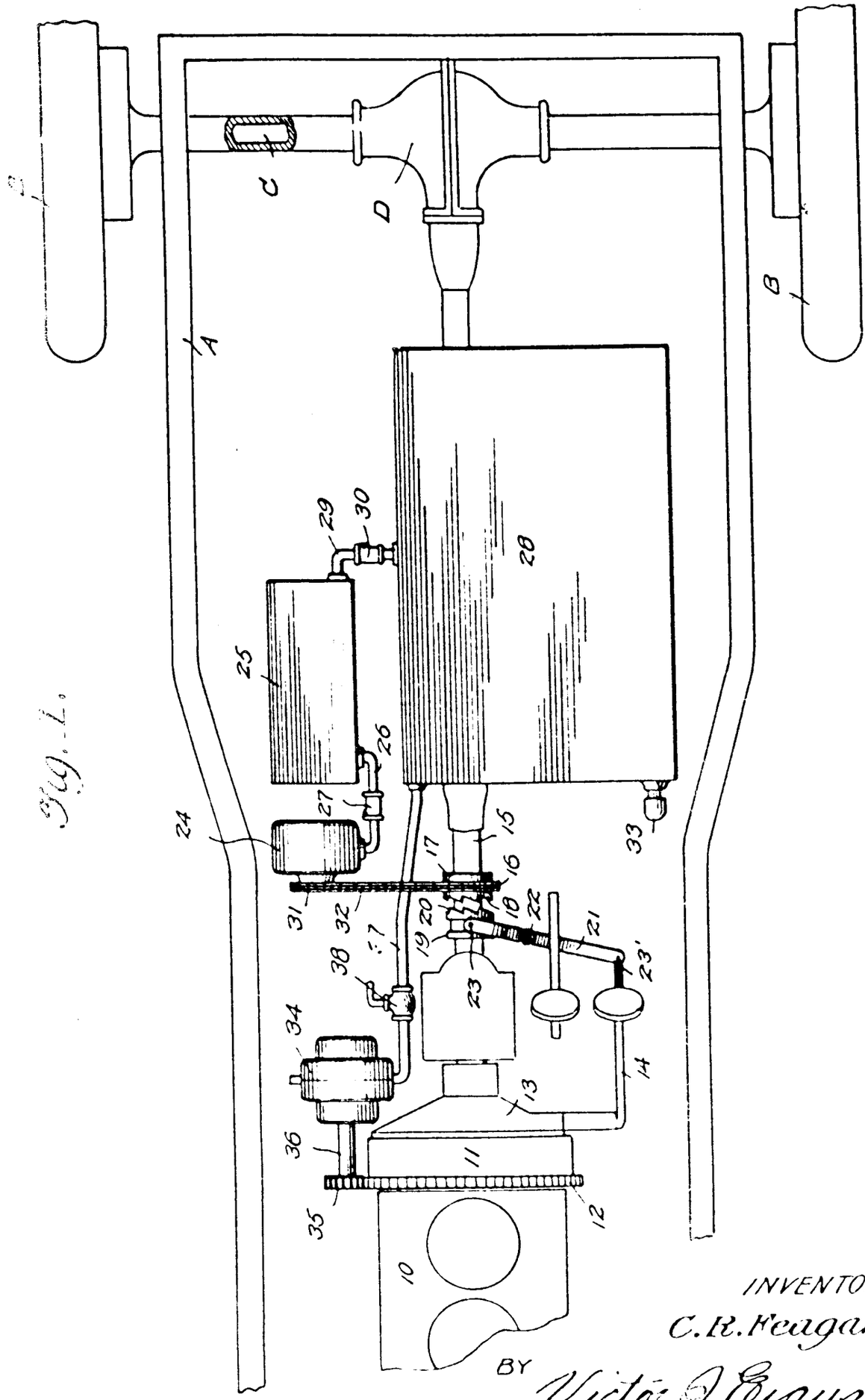


Fig. 1.

INVENTOR

C. R. Feagan,

BY Victor J. Evans

ATTY.

C. R. FEAGAN.

AIR EQUIPMENT FOR AUTOMOBILES.

APPLICATION FILED APR. 4, 1919.

1,347,805.

Patented July 27, 1920.

2 SHEETS-SHEET 2.

Fig. 3.

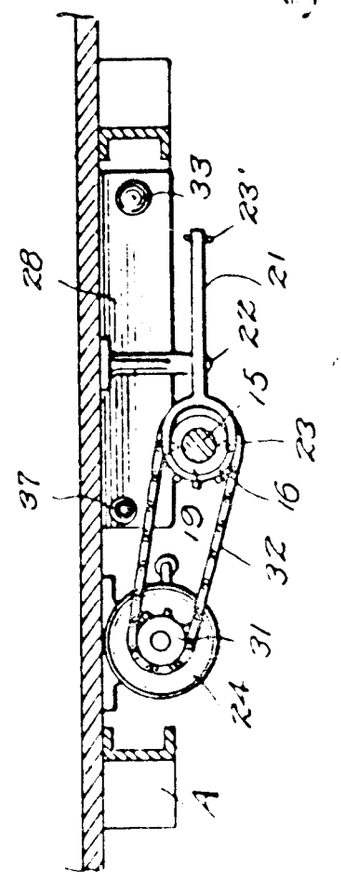
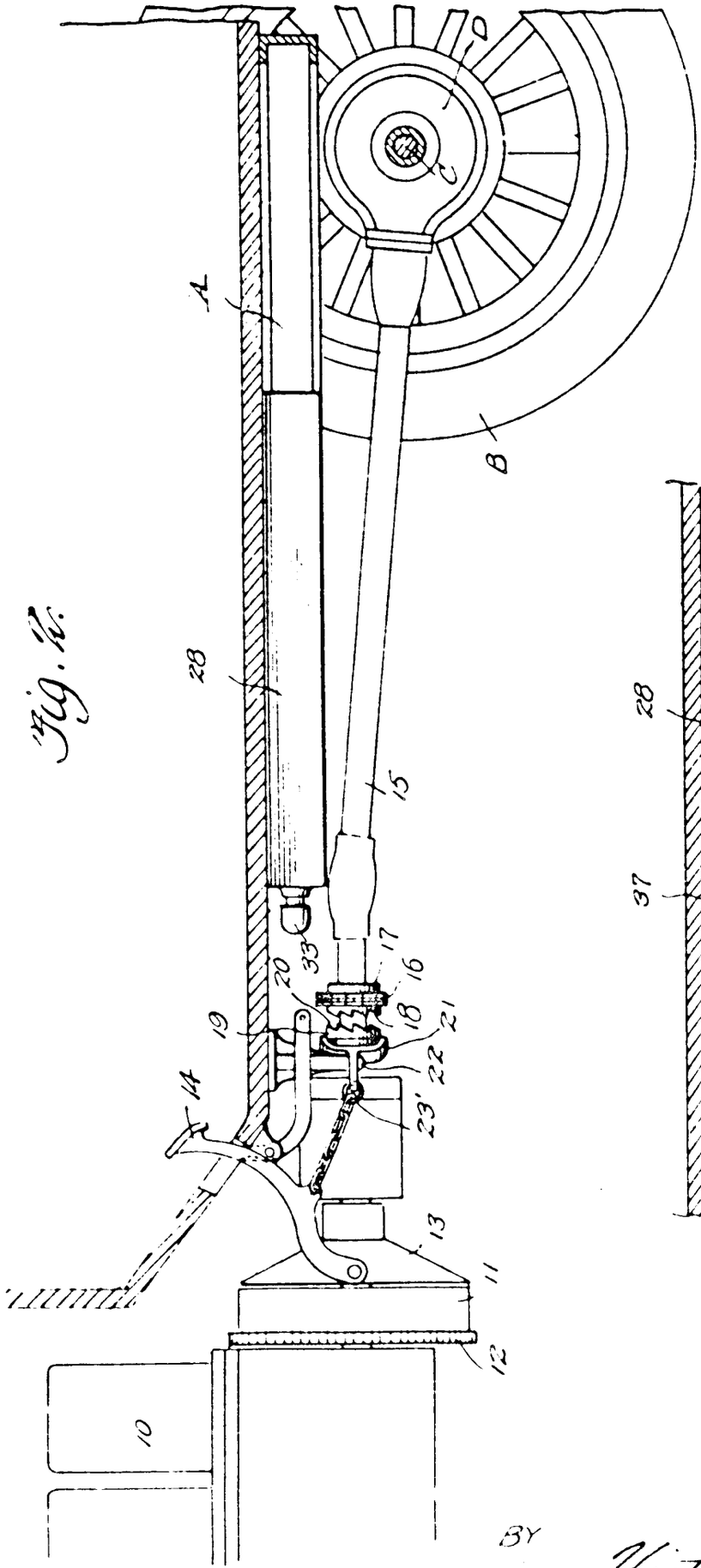


Fig. 4.



INVENTOR

C. R. Feagan,

BY

Victor J. Evans

ATTY.

UNITED STATES PATENT OFFICE.

CHARLES R. FEAGAN, OF DETROIT, MICHIGAN.

AIR EQUIPMENT FOR AUTOMOBILES.

1,347,805. Specification of Letters Patent. Patented July 27, 1920.

Application filed April 4, 1919. Serial No. 287,456.

To all whom it may concern:

Be it known that I, CHARLES R. FEAGAN, a citizen of the United States, residing at Detroit, in the county of Wayne and State of Michigan, have invented new and useful Improvements in Air Equipments for Automobiles, of which the following is a specification.

This invention relates to automobiles and has particular reference to an apparatus applicable to the same which is adapted to generate and store a supply of compressed air for use in starting the motor.

One of the principal objects of the invention is the provision of a drive shaft, an axle having keyed supporting wheels with a driven connection therebetween, a power plant and a clutch and an apparatus for creating energy, mechanism between the drive shaft and said apparatus for operating the latter, said clutch serving when the power plant is thrown out of operation to render the energy creating mechanism active through inertia of the drive shaft.

Another object in view is the provision of an apparatus of the class described, which derives its supply of energy from a pump operated by the drive shaft after the same has been uncoupled from the motor, thus utilizing the momentum of the car for a source of motive power for said pump.

A further object of the invention is the provision of an apparatus for creating and compressing air within the tank for use in starting the motor, said apparatus being adapted to be operated by the drive shaft through suitable means by the momentum of the car after the power from the motor has been shut off and said compression in the pump reacting as a means to gradually bring the car to a stop, thus not only utilizing the wasted energy and wear on the brake bands but saving fuel now commonly used as a means to compress the air.

Another object of the invention is to provide a device of the class described which includes a high pressure tank and a low pressure storage tank, the high pressure tank having direct communication with the energy creating mechanism, said high pressure tank maintaining a constant pressure at all times, in order to effect an immediate braking action on the drive shaft irrespective of the pressure in the storage tank.

A still further object of the invention is the provision of a combination apparatus acting as a means for compressing air in a storage tank and serving as a brake for the vehicle, said brake equally distributing its force to each of the drive wheels, thus avoiding skidding due to an unequal distribution of the braking power to each wheel, which is not uncommon in vehicles depending entirely upon brake bands.

A further object of the invention is the provision of an apparatus of the class described in which the weight of the same is equally distributed, which is inexpensive to manufacture and which may be readily installed on any standard automobile.

With these and other objects in view the invention resides in a novel construction, combination and arrangement of parts fully described and pointed out in the following description and claims and illustrated in the accompanying drawings in which:

Figure 1 is a plan view of the device applied to in its supplied position.

Fig. 2 is a fragmentary longitudinal sectional view of the same.

Fig. 3 is a detail cross sectional view therethrough.

In the drawings A designates the chassis of an automobile which is provided with the usual drive wheels B keyed to the rear axle C and driven by a differential D. The power plant or motor 10 is provided with a fly wheel 11 having a gear 12 formed on the outer periphery thereof. A clutch mechanism 13, provided with a foot operating lever 14 is interposed between the power plant and a drive shaft 15, the latter being operatively connected with the differential D. Loosely mounted on the drive shaft and keyed against longitudinal movement is a sprocket wheel 16 provided with a hub 17 having a clutch surface 18. A clutch member 19 is splined to the drive shaft 15 adjacent the hub 17 and provided with a clutch surface 20 which is adapted to be thrown into operative engagement with the clutch surface 18 whereby the sprocket

wheel 16 is operatively connected with the drive shaft for turning movement therewith. A lever 21 is pivoted at 22 and connected at 23 to the clutch member 19 for moving the same into and out of engagement with the hub 17. The opposite extremity of the lever 21 is connected to the clutch lever 14 as at 23 whereby upon throwing the clutch 13 out of action and thus uncoupling the power plant from the drive shaft, the sprocket wheel 16 is automatically operatively connected with t' drive shaft 15. An air pump 24 is connected with a high pressure storage tank 25 by means of a conduit 26 having a check valve 27 arranged therebetween. A low pressure storage tank 28 is connected with the high pressure tank 25 by means of a conduit 29 which is provided with a high pressure check valve 30. The air pump 24 is provided with a sprocket 31 and a sprocket chain 32 operatively connects the sprocket wheels 31 and 16. The main storage tank is provided with a safety valve 33 which relieves the main storage tank of any excess pressure, the escape of the same being adapted to pass out through the muffler from the power plant. A suitable air motor 34 is provided with a gear 35 on its drive shaft 36 and is supplied from the tank 28 by the conduit 37. A valve 38 is arranged in the conduit 37 and is adapted to be operated from the dash board of the vehicle by any suitable means for starting the motor. The gear 35 meshes with the gear 12 on the fly wheel 11 in order to turn over the crank shaft of the power plant.

In operation of the device when the operator of the vehicle throws the clutch 13 out in order to uncouple the power plant from the drive shaft, the clutch surfaces 20 and 18 are automatically engaged by means of the lever 21 thus operatively connecting the sprocket wheel 16 with the drive shaft which revolves through inertia under the momentum of the car and operates the air pump 24 generating a supply of compressing air which is forced into the high pressure tank 25 and subsequently into the low pressure storage tank 28. The resistance necessarily consumed in compressing the air causes the drive shaft 15 to gradually slow down, thus acting as a brake on the rear axle to which the wheels B are keyed. It will thus be seen that the vehicle will be gradually brought to a stand still by the resistance offered in compressing the air and it will be further noted that the momentum of the car will be utilized as a means for storing a supply of compressed air which may be used for starting the motor or any other purpose desired. It might be here noted that the pressure in the high pressure tank 25 always remains constant, irrespective of the pressure in the low pressure storage tank 28, thereby immediately effecting a braking action on the drive shaft when the clutch is thrown to a position to uncouple the drive shaft from the power plant. The usual band brakes may be used in connection with the device for bringing the vehicle to a sudden stop in case of emergency.

While I have shown and described a simple and preferred form of carrying my invention into practice I do not care to be limited to the exact details therein exhibited but reserve the right to make such changes and alteration as necessarily fall within the scope of the appended claims.

What is claimed as new is:

1. In combination, a drive shaft, an apparatus for creating energy, high and low pressure tanks operatively connected with said apparatus for storing energy created by said apparatus and for exerting a retarding influence on said apparatus, mechanism between the drive shaft and said apparatus for operating said apparatus, a power plant, a clutch between the drive shaft and the power plant, and means on the drive shaft serving to couple the energy creating apparatus therewith to render said apparatus active through momentum of the drive shaft when the power plant is thrown out of engagement therewith.

2. A drive shaft, an apparatus for creating energy, high and low pressure tanks operatively connected with said apparatus for storing energy created by said apparatus and for exerting a retarding influence on said apparatus, mechanism between the drive shaft and said apparatus for operating the said apparatus, a power plant, a clutch between the drive shaft and the power plant, and means on the drive shaft serving to couple the energy creating apparatus therewith to render said apparatus active through momentum of the drive shaft when the power plant is thrown out of engagement therewith, an axle having keyed supporting wheels, and a driven connection between the axle and said drive shaft.

3. A driven wheeled axle, a drive shaft operatively connected with said axle, a high pressure tank, a low pressure tank communicating with the same, a compressor operatively connected with the high pressure tank, mechanism between the drive shaft and the compressor for operating the compressor, a power plant, a clutch mechanism between the drive shaft and said power plant, and means coacting with said clutch mechanism serving when the latter is at one adjustment to render the compressor active, to disconnect the drive shaft from the power plant and simultaneously to retard the momental action of the wheeled axle.

4. The combination with a vehicle, having a motor, a drive shaft therefor and a

clutch for coupling said motor to the drive shaft, of an apparatus for generating and storing compressed air, comprising a high pressure tank, a low pressure storage tank communicating with the same, an air compressor communicating with the high pressure tank, and means for transmitting motion to said compressor from the drive shaft, said means becoming active upon the operation of the clutch to uncouple the motor from the shaft.

In testimony whereof I affix my signature.

CHARLES R. FEAGAN.

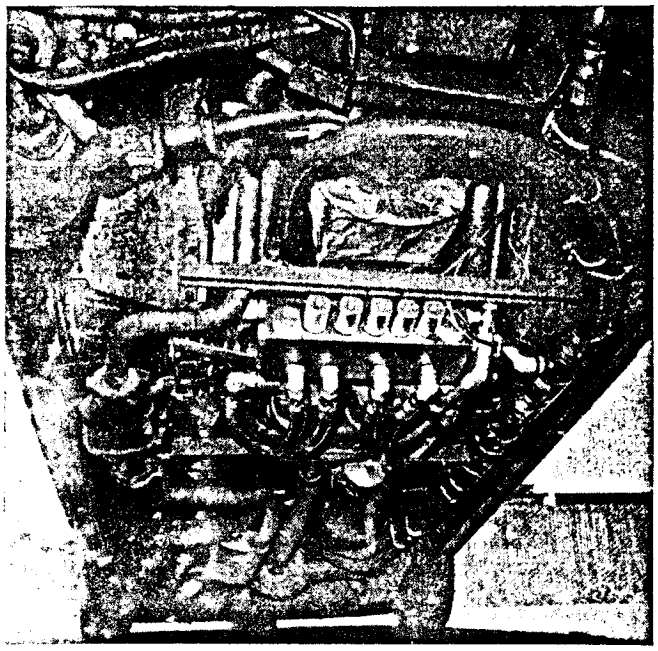
MECHANIX ILLUSTRATED

NOVEMBER 1977

A Car That Can Store Power

By Wayne Thoms

MILEAGE tests using identical Granadas, one equipped with an Inertial Storage Transmission (IST) and the other with a stock Six, showed that the IST car (in lead) more than doubled gas mileage, even in big-town traffic.



UNDERCARRIAGE of IST Granada (left) shows the engine, solenoids, manifold, tubing and combination pump/motors. The engine is standard but it shuts down when on-board computer adds stored power.

BELOW: Our cover illustration and diagram which explains how the engine drives a pump, sending fluid under pressure to hydraulic motors at rear. Motors drive wheels. Manifolds are control boxes, as explained in the text.

WE SAT at a Portland, Ore stop signal in total silence engine off. As the light changed the car took off noiselessly. The engine remained eerily hushed as we accelerated to normal speed. Because of the silence, fellow motorists might have thought we were being pushed by some mystical force—but there was no magic involved.

We were tooling around town in a specially-equipped Ford Granada that may wind up as a forerunner of things to come. Under the hood there were some unusual noises of pumps engaging and gears meshing. We also experienced the sensation of uneven acceleration motions which convinced us this was a demonstration prototype. But we *were* moving. And without the benefit of the regular engine.

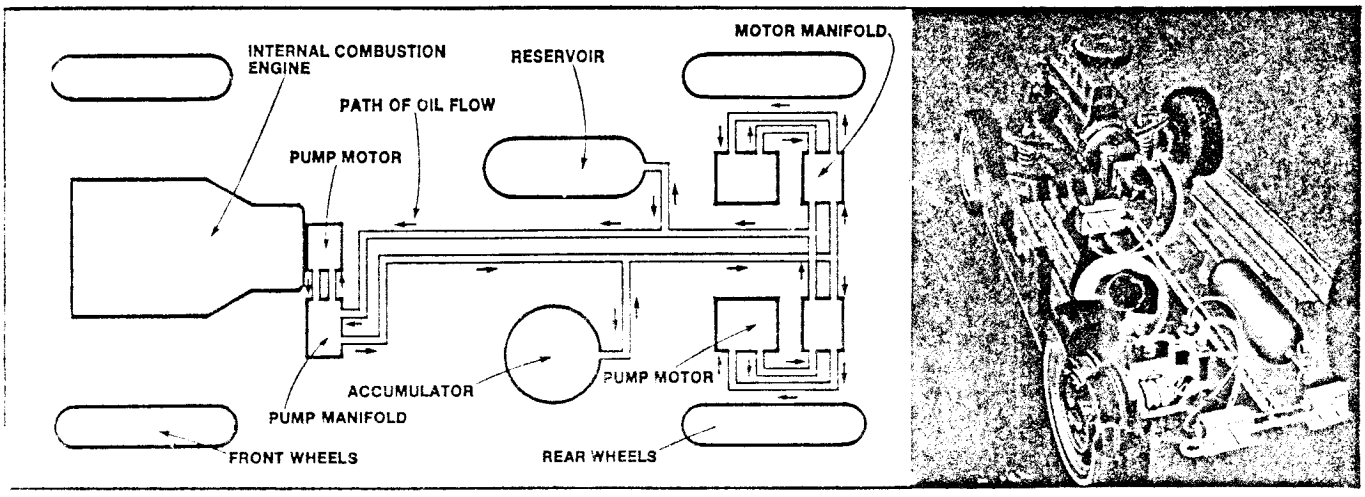
What was moving the car? Stored hydraulic pressure of the sort used in gas station lifts.

The name given to the invention —Inertial Storage Transmission (IST) —could lead a guy into thinking that the car is powered by a transmission. It's not. Actually, the spot where the Granada's transmission used to be is occupied by a hydraulic pump/motor. And the entire drive train has been replaced by a system that stores excess power and uses it when needed instead of throwing it away.

The idea of hydraulic drive is not new, nor is it very complex. What *is* new is the idea of storing an engine's excess power.

Our opinion: It works. We rode in the prototype automobile, drove it and, most important, witnessed an amazing demonstration of fuel economy—savings of over 100 percent. More about that later.

How does it work? The idea involves the reworked drive train, in-



cluding three special hydraulic pumps that also function as motors. That is, each serves as a pump some of the time and as a motor at other times.

Other parts include two manifolds equipped with solenoids and valves to control the direction of pumped oil. There's also an oil reservoir. And the key to the whole works: a spherical tank called an accumulator that stores energy in the form of oil pressure. A small computer acts as the brain for the whole system.

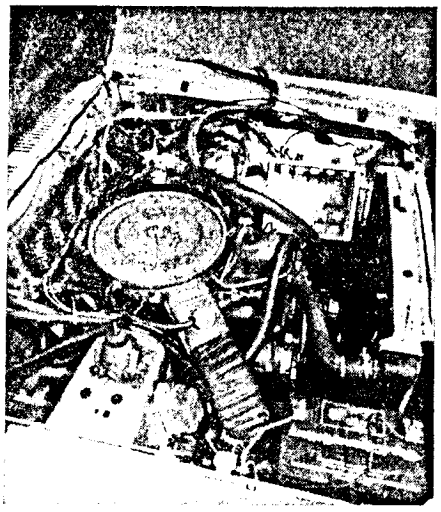
Most of the action takes place in the pumps. One of the pumps (which are made by Volvo) is connected to the engine and acts as both starter and pumper. The other two are used as motors and also for regenerative braking—pumping oil as the car slows. The oil reservoir feeds the accumulator tank.

Out on the road, the car engine drives the hydraulic pump behind the engine. Heavy-duty tubing runs from that pump to the other two pumps which serve as drive motors. Power not required to drive the wheels is stored in the accumulator. When pressure in the accumulator reaches a predetermined point (about 2,500 psi), the internal combustion engine is switched off by the computer. Then pressure stored in the accumulator drives the two pumps (which are acting as motors) at the wheels. When pressure is used up, the computer gets the engine going again (using the pump behind the engine as a starter) and the cycle begins again.

When the car engine is going it runs at a constant (and efficient) speed of about 3,500 rpm, because it drives pumps and not the car wheels directly. The engine shuts off when the car is stopped. There is no wasted fuel at idle.

Stopping, cruising on level ground or running downhill pumps excess power into the accumulator. As pressure in the tank rises, the gasoline engine switches off automatically and the car runs on stored power. The hydraulic-to-internal combustion energy cycle repeats automatically as pressure is stored and used.

Vince Carman, president of an outfit called Global Scientific Engineers, Inc., and inventor of the drive system, is a former NASA scientist who turned to independent development when the space program tapered off. He's proud of the way his invention performs, with good reason.



UNDERHOOD of test car reveals extra manifolds and a pressure monitor that feeds information to an electronic brain.

INSIDE: Dashboard gauges indicate tank pressure. Technology of IST car is simple, uses conventional, off-the-shelf parts.

GAS-MILEAGE gauge of test car is checked, then compared to non-IST model. The test car won with 38.4 mpg.

Our fuel-economy test pitted the IST-equipped Granada against a stock Ford Six. Both were equipped with 1/10-gal. fuel bottles, standard for measuring fuel economy.

Both cars began with full bottles. Drivers navigated through city traffic, the IST-equipped car in the lead. When the stock machine ran out of gas, we measured the fuel remaining in the IST car's bottle. The stock Ford got 16 mpg, the IST machine a remarkable 38.4 mpg. And the standard Ford was *lighter*, weighing 3,580 lbs., while the IST vehicle, with experimental equipment, weighed 4,120 lbs.

How is the IST car to drive? Not exactly normal but, then again, not totally crazy. We simply turned on the ignition, flipped a switch for forward or reverse and stepped on the accelerator. The first start after the car has been parked is always with stored hydraulic power. There is at least enough to get out of the driveway and start down the street.

We could feel the two levels of drive motors cutting in as we applied pressure on the accelerator. And foot pressure is where the IST differs from the conventional—it is necessary to play with the accelerator more than with a standard auto. If the foot is lifted abruptly, both drive motors act as brakes. It feels as though someone tossed out an anchor. In fact, we never touched the brake pedal during the test drive. It took only a couple of minutes to master the art of controlling the accelerator, using it both for stop and go. Carman explained that he plans adjustments which will let the driver be less concerned with pedal position.

What about power accessories. Power steering could be operated from the hydraulic power, as could power brakes. The only problem may be with air conditioning. Under the present arrangement, *everything* is off when the car is stopped. That means no power for turning an A/C compressor. A/C could be driven by a separate motor but it would lower overall mpg.

What about the hazard of an accumulator charged to 3,500 or 4,000 psi of oil pressure? In a production vehicle, the pressure would be contained in a 5- to 7-gal. spherical container, which is the strongest shape. For now, should the accumulator rupture in an accident (explosion is virtually impossible), leakage would start at the weakest

point (the outlet neck) and pressure would be slowly released. In simple terms, the accumulator pressure tank is probably safer than an ordinary gasoline tank.

The oil reservoir from which the accumulator draws fluid is not pressurized and presents no hazards at all.

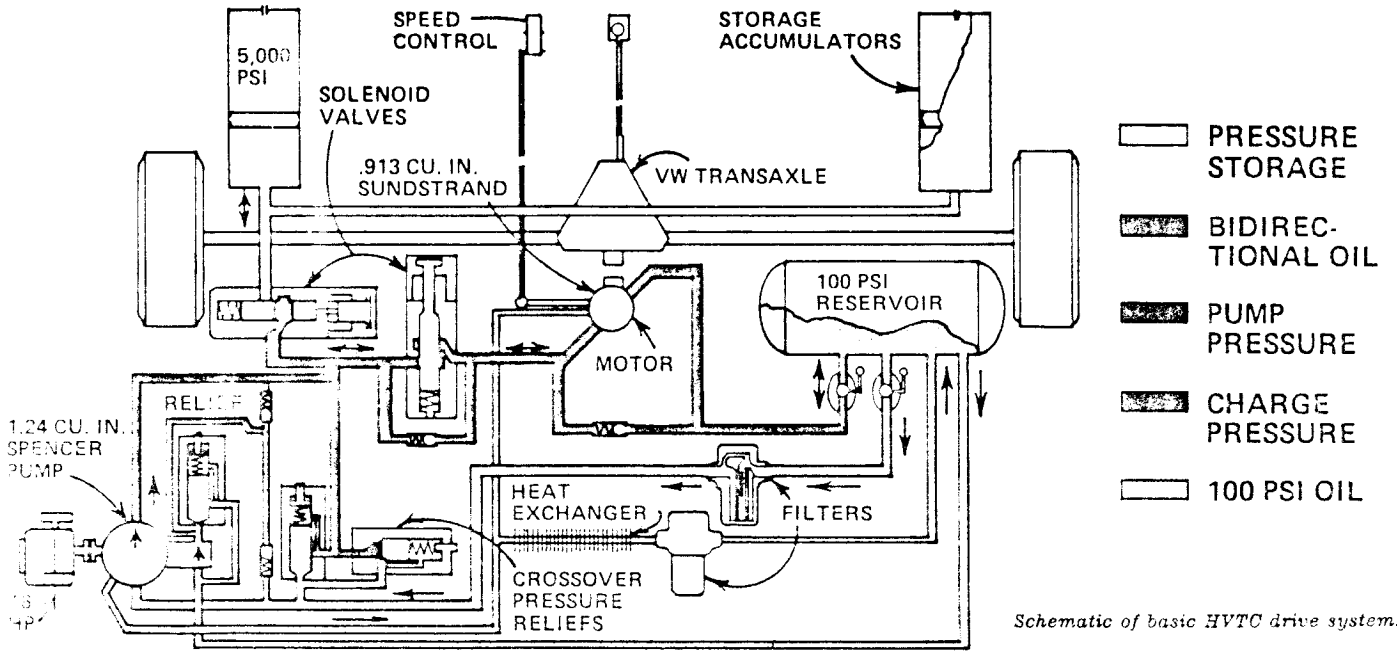
An IST vehicle would be an environmentally clean vehicle, too. When used as most people drive —short hauls in an urban environment—it is incredibly economical. Carman estimates that an IST car would only cost $50 to $100 more to build than an ordinary Detroit wagon.

Where is IST going? Carman has been operating on private funds, a situation that is naturally limiting. If the government provides money, IST could start life as a production delivery vehicle or transit bus. From there it would be a short jump to small, efficient commuter-type cars. Without financial help, development to a commercial level may take longer.

We were impressed with Carman's car. There could be an IST car in our future and it could be added to the list of ways to preserve our dwindling supplies of fossil fuel.●

THIS CAR TRAVELS 75 MILES ON A SINGLE GALLON OF GASOLINE!

THE MOTHER EARTH NEWS® MARCH/APRIL 1978



Schematic of basic HVTC drive system.

IT seems that Portland, Oregon's Vincent Carman (see "Can This Transmission *Really* Double Your Car's Mileage?" in MOTHER NO. 48) isn't alone. At least one other group of inspired experimenters has found a way to use hydraulics to vastly increase an automobile's gas mileage.

That group is a class of advanced students at Minneapolis, Minnesota's Hennepin Vocational Technical Center. And under the guidance of instructor Ernie Parker (and without ever having heard of Vince or his Inertial Storage Transmission), the class recently designed and built what they call a "hydraulic storage transmission".

Does it work? It sure does! As the students have already demonstrated, when their special drive train is coupled to a 16-hp Tecumseh engine, installed in a Volkswagen chassis, and covered with a Bradley GT body . . . the resulting one-of-a-kind automobile will travel (at speeds up to 70 mph) an incredible 75 miles on a single gallon of gas.

That's impressive, especially when you remember that the HVTC fuel-stretcher was entirely constructed from off-the-shelf components that are readily available to any home mechanic in any part of the country. The sleek little automobile contains absolutely no exotic technology or hardware at all.

IT ALL BEGAN IN 1920

The HVTC class project was originally launched because of a 1920 magazine article brought in by student Tom Steincamp. The piece described an automobile with a hydraulic drive train and labeled the vehicle "the car of the future". Some library research and a few group discussions soon convinced the class that the idea was a good one . . . but that it would be even better if an energy saving accumulator was added to the hydraulic system.

Before long Parker's crew had roughed out a preliminary design of the new hydraulic drive. And the concept looked so good on paper that the group simply decided to go ahead and build one to see how it would work.

THE FIRST PROTOTYPE WAS A DUD

Parker's students quickly scrounged up a well-used VW chassis, a 60-hp VW engine, and enough hydraulic odds and ends to assemble a crude prototype of their design. It was a disappointment. The vehicle ran well enough, but it consumed only slightly less gasoline than a stock Volkswagen.

"This thing's got just too much horsepower," someone said. "Maybe a VW with a stock transmission needs 60 hp to get around . . . but with the hydraulic drive train we've designed, I think a Volkswagen can get by with one heck of a lot less muscle."

Everyone agreed and the team of experimenters quickly rounded up a tow vehicle and began running a series of "drawbar tests" to determine the *least* amount of engine they needed to adequately power their 1,800-pound car. Result: The students concluded that a 16-hp Tecumseh overhead valve powerplant would do the job . . . provided that their VW chassis was enclosed in a very aerodynamically clean envelope. (Say, something like the Bradley GT body that somebody just happened to want to donate to the project!)

HVTC CAR NUMBER TWO WORKS!

Just as Ernie Parker's engineering team was finishing its second-generation "fluid powered" carriage, the opportunity arose to enter the machine in a Minnesota Society of Automotive Engineers economy run.

The test course was a 100-mile "average" trip (one-third city, one-third suburban, and one-third country driving) and the HVTC vehicle had less than one mile on it when the rally began. As far as this particular car was concerned, then, the run was far less a competition than a shakedown cruise to flush out the bugs which always hide in every new engineering concept.

Sure enough, the HVTC automobile had its share of gremlins . . . one of which was so serious that the car rolled up "only" a "disappointing" 50 mpg. As instructor Parker explains it:

"A valve we had changed the evening before vibrated closed, thus starving the vehicle's hydraulic pump of oil. If we'd mounted the valve's lever just 90 degrees to the left *or* to the right, this wouldn't have happened. The mistake really murdered us in the competition, though, because—with that valve closed—our car's engine had to pump twice as much oil as necessary to push the machine down the road."

Were the HVTC students licked by this less-than-ideal first public showing of their hydraulically driven automobile? Of course not! They just pitched in, exorcised the imps and goblins from the car, and put the machine back on the road. Further tests soon showed that the vehicle's combination of [1] aerodynamic body, [2] 16-hp engine, and [3] "infinite gear ratio" hydraulic drive and energy storage system is a real winner.

The little car will accelerate from 0 to 60 miles per hour in a very satisfying eight seconds. Furthermore, under "no wind" conditions, the automobile can cruise down the highway at a steady 70 mph . . . while carrying a reserve in its accumulators that will push it on up to higher speeds for a short distance. And it does all this on a maximum fuel consumption of .9 gallons per hour . . . which works out to a shade better than 75 *miles per gallon*. (Are you paying attention, Detroit?)

Still, Ernie's class is quick to point out that its car can be improved a great deal more. One of the most obvious refinements, the students say, will be the elimination of the vehicle's VW transaxle. "We left the transaxle in so we wouldn't have to redesign the VW chassis's suspension," they point out, "which means—since nothing is 100% efficient—that we've combined the inefficiencies of our hydraulic drive with the well-known inefficiencies of the old mechanical drive. If and when we couple our hydraulic motor directly to the car's wheels, we should realize a marked improvement in our car's efficiency."

THE SAME, YET DIFFERENT

The Hennepin Tech students' energy storage transmission is, in some ways, quite similar to Vince Carman's Inertial Storage Transmission featured in MOTHER NO. 48. Both use off-the-shelf hardware and well-proven technology. Both dramatically extend an automobile's gasoline mileage by capturing, storing in an accumulator, and later using the energy that ordinary automobiles normally waste during braking and when they are idled in city traffic with their engines running.

But the two transmissions are quite different too. Carman, for instance, uses "fixed displacement" pumps and motors in his hydraulic drive train because he feels that they're the most efficient . . . while the HVTC student team chose "variable displacement" hardware because such pumps and motors are easier to control.

Another major difference: The Portland car's engine is run at a constant rpm and is turned off as soon as it has pumped a predetermined pressure into the accumulator in its hydraulic drive line. In the Minneapolis vehicle, on the other hand, the engine's rpm is allowed to vary according to the amount of pressure that is in the drive line's accumulator and how fast that pressure is being drawn off . . . and the powerplant is almost never shut completely down while the car is moving.

The two vehicles' speed control systems work differently too. Any time the operator's foot is removed from the accelerator in Vince's car, the automobile is automatically put into a "braking mode". (The car is rapidly slowed down as the turning of the rear wheels runs a pump which pushes hydraulic fluid into the drive line's accumulator.) The accelerator pedal on the HVTC machine, however, is pivoted in the middle. When the driver pushes with his or her toe, the car speeds up. Heel pressure throws the system into braking mode and rapidly slows the vehicle down. And when the operator removes his or her foot from the pedal altogether, the car's drive system switches into a freewheeling neutral, and the machine coasts.

IS THE HVTC CAR IN *YOUR* FUTURE?

Even though Ernie Parker's class fabricated its "car of the future" from standard hardware that's available to any family mechanic (or Detroit engineer) today, it's doubtful that GM, Ford, or Chrysler will start cranking out carbon copies of the HVTC automobile any time soon. If you want one of the 75-mpg vehicles for your own use . . . well, you'll probably have to put it together yourself.

And maybe MOTHER will be able to help make that possible. Naturally, a great deal of testing remains to be done on the HVTC concept, the design will undoubtedly be refined as time goes on, etc. But this magazine's editors intend to monitor the work of Ernie Parker's group closely, do what we can to help the engineering team hone and develop its ideas . . . and keep you informed of the progress that is made. Perhaps, before too long, we'll even be able to offer you plans that you can use in the construction of your own 75-mpg "car of the future".

United States Patent [19]

Yeh

[11] **4,163,367**

[45] **Aug. 7, 1979**

[54] **HYBRID FLYWHEEL/COMPRESSED-FLUID PROPULSION SYSTEM FOR NONSTATIONARY APPLICATIONS**

[76] Inventor: **George C. Yeh**, 2 Smedley Dr., Newtown Square, Pa. 19073

[21] Appl. No.: **867,694**

[22] Filed: **Jan. 9, 1978**

[51] **Int. Cl.**[2] **F15B 1/02**

[52] **U.S. Cl.** **60/414;** 60/416; 60/643; 60/668; 180/165; 180/302

[58] **Field of Search** ..... 60/371, 407, 408, 413, 60/414, 416, 643, 659, 668, 698, 701; 180/44 F, 44 M, 65 A, 66 B; 74/572

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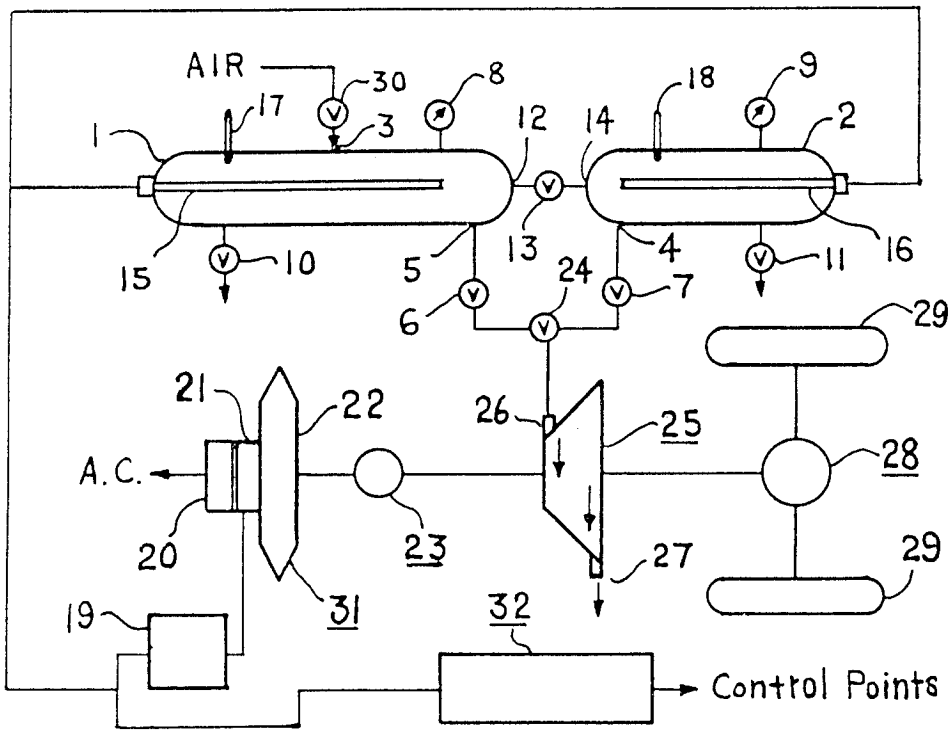
Primary Examiner—Edgar W. Geoghegan
Attorney, Agent, or Firm—James Albert Drobile

[57] **ABSTRACT**

The adaptation of a compressed-fluid (such as compressed-air) powered turbine in conjunction with the use of a flywheel as a hybrid propulsion system for nonstationary applications, such as vehicle drive, is shown and its practicality demonstrated. This propulsion system requires a nonpolluting fluid, such as air, and a source of mechanical or electrical energy to compress said fluid and energize said flywheel, both of which act as energy storage media. An expander/compressor unit, such as a turbine, is used for converting the stored energy of said compressed-fluid into shaft power by expanding said fluid, and recovering the braking energy during vehicle deceleration by compressing and storing the atmospheric air (if air is used). Said flywheel is used not only for providing peak powers necessary for vehicle acceleration but also for recovering the braking energy during vehicle deceleration and refilling said compressed-fluid in an emergency. The propulsion system can use the unlimited supply of air as the primary energy-storage medium and said flywheel as the secondary energy-storage medium. The propulsion system is not only regenerative but also quick-recharging; it, therefore, has high energy-efficiencies and broad applications.

6 Claims, 2 Drawing Figures



HYBRID FLYWHEEL/COMPRESSED-FLUID PROPULSION SYSTEM FOR NONSTATIONARY APPLICATIONS

BACKGROUND AND OBJECTS OF THE INVENTION

This invention relates to hybrid propulsion systems for nonstationary applications, such as vehicle drive, farm-machine drive, boats, etc., and more particularly to the adaptation of a hybrid flywheel/compressed-fluid propulsion system as a power drive for nonstationary applications. Compressed-fluids, such as compressed-air, have been used as an energy-storage medium for driving energy converters, such as turbines, which act as process plant drivers for many decades. Although many successful stationary applications of a compressed-air turbine can be found in various industries, very few nonstationary applications of the same have been reported in the literature. This is because the limited energy-storage capacity of a compressed-fluid that results in a restricted operating range makes its application impractical or economically infeasible.

Significant advances have been made recently in the structural materials and designs of high-pressure vessels. High-pressure compressors have also improved greatly over the years. Now, it is practical to generate and store a compressed-fluid at pressures over 30,000 pounds per square inch. Today, high-pressure vessels and compressors are lighter and more compact than they were twenty years ago due to the lighter and better structural materials and the advanced designs used. But, this will still result in a limited supply of energy of a compressed-fluid when used in nonstationary applications, such as vehicle drive. Therefore, every practical step must be taken to maximize the use of this limited energy supply if it is to be viable for nonstationary applications in this time frame.

In spite of the limited supply of energy, a compressed-fluid is an attractive energy-storage medium especially when compressed-air is used for vehicle drive since it has several advantages over other available energy-storage media. These advantages are: (1) truly nonpolluting; (2) using the unlimited supply of air; (3) having high energy efficiencies; (4) the braking energy can be recovered substantially; (5) fewer moving parts requiring little maintenance; (6) long service-life; (7) quick-recharging, etc.

While vehicle range may be improved by using lighter materials and improved designs it will still be governed by the energy stored in the compressed-fluid as well as the way the vehicle is used. The range of a vehicle driven by a compressed-fluid propulsion system will be very much dependent on many factors which fall into two major categories. The first is concerned with the compressed-fluid itself and includes such factors as the initial pressure, temperature, and volume. The second is concerned with the way in which the vehicle is operated and includes the total weight, the vehicles speed, the number of starts and stops per driving cycle, the acceleration, the wind conditions, the road-surface conditions, and the variation from a level route. In general, increased performance in these operational categories requires higher fluid-pressures and volumetric flow-rates from compressed-fluid, resulting in less total energy being available for traveling.

According to the results of studies made by this inventor, a key to improving vehicle range is to remove

the requirement for peak powers from the compressed-fluid propulsion system in the operational categories described above. The results also indicated that once the vehicle has reached its maximum speed, the power requirement for maintaining its speed is approximately one fourth of the peak value. At this point in the driving cycle, if the vehicle velocity is held constant, the power requirement of the vehicle is approximately equal to the losses due to the expander, drive trains, aerodynamic drag, and the rolling resistance of the tires. My above studies have concluded that the peak power requirements during vehicle acceleration greatly reduce the available energy supply of the compressed-fluid for traveling. Therefore, it is essential to provide a system which can prevent these peak power drains in the compressed-fluid propulsion system used for vehicle drive. My studies further indicated that a second key to improving vehicle range is to recover the braking energy when the vehicle decelerates. Without the use of a recovery system, the kinetic energy generated through a propulsion system, such as a compressed-air turbine, will be dissipated partly in the frictional braking system as heat and partly in the rolling resistance and vehicle drag as it decelerates.

The main object of this invention is to provide a viable compressed-fluid propulsion system, such as compressed-air, for nonstationary applications, especially for vehicle drive by combining with a secondary power source capable of reducing peak powers drained in the compressed-fluid propulsion system during the acceleration cycle and recovering the braking energy during the deceleration cycle.

Other important objects of this invention are: (1) to provide a truly nonpolluting propulsion system for nonstationary applications, especailly vehicle drive; (2) to provide a propulsion system for nonstationary applications, especially vehicle drive, which utilizes power-storage media capable of quick-recharging; (3) to provide a propulsion system for nonstationary applications, especially vehicle drive, which contains a regenerating system for recovering the braking energy and which operates with high energy efficiencies; (4) to provide a propulsion system for nonstationary applications, especially vehicle drive, which requires little maintenance and which has a long service life, etc.

DETAILED DESCRIPTION OF THE INVENTION

The above objects of the invention are achieved by the adaptation of a suitable compressed-fluid propulsion system, preferably a compressed-air interacting with an expander/compressor unit, and a regenerative flywheel system to provide the peak powers required during vehicle acceleration and recover the braking energy during vehicle deceleration. According to the present invention, the braking energy can be recovered also by the use of said expander/compressor unit acting as a compressor to compress the atmospheric air using the shaft power transmitted from the drive trains of the vehicle, and store the compressed air generated in a tank in order to use it with the vehicle's original compressed-air supply, which can perform the work of expansion through said expander/compressor unit to produce the shaft power for transmitting to the vehicle's drive trains.

No where in the literature known to me is there a report of the use of a hybrid flywheel/compressed-fluid

propulsion system for nonstationary applications, such as vehicle drive.

The results of initial studies made by this inventor indicated that approximately 75% to 90% of the braking energy can be recovered by the use of the regenerative flywheel and the regenerative compressed-air propulsion system proposed by this invention. The results also show that with three stops per mile, the range of a compressed-air powered vehicle traveling at an average speed of fifty miles per hour can be doubled for a given compressed-air supply, by the use of said regenerative systems provided by this invention, assuming that both the expander/compressor unit and the flywheel have a mechanical efficiency of 90%.

In the following, the invention will be discussed in detail by reference to the specific preferred embodiment and the typical installation of the invention shown in the accompanying drawings, FIGS. **1** and **2**.

FIG. **1** is a detailed diagramatic illustration of a preferred embodiment of the hybrid flywheel/compressed-air powered vehicle drive provided by this invention. The high-pressure tank **1** has the inlet **3** and the control valve **30** to receive the initial supply of compressed-air at a maximum pressure. The maximum air pressure can be regulated by the use of the relief valve **10** and the pressure gauge **8**. The air temperature inside said tank **1** can be controlled by heating the air electrically with the electrical heater **15**, the thermometer **17** indicating the temperature of the air in the tank.

During vehicle acceleration, the compressed-air in said tank **1** is discharged at a desired pressure and volumetric flow-rate through the outlet **5**, the control valve/pressure regulator unit **6** and the three-way valve **24**, and flows into the expander/compressor unit **25** through its high-pressure air inlet **26**. For vehicle acceleration, said expander/compressor unit **25** acts as an expander to convert the work of expansion performed by the compressed-air into shaft power, which is then transmitted to the drive train/differential unit **28** for driving the wheels **29**. The expanded-air leaves said expander/compressor unit **25** through its low-pressure air outlet **27** into the atmosphere.

During vehicle deceleration, the vehicle kinetic energy is transmitted through said wheels **29** and said drive trains/differential unit **28**, to said expander/compressor unit **25**; and as a result, said expander/compressor unit **25** turns to take in the atmospheric air through its low-pressure inlet **27**, which also acts as the low-pressure air outlet during vehicle acceleration as described above. The air taken in is compressed, and then leaves the high-pressure air outlet **26**, which also acts as the high-pressure air inlet during vehicle acceleration as already described above. The newly generated compressured-air is led through said three-way valve **24**, the control valve/pressure regulator unit **7** and the air inlet **4** into the low-pressure tank **2**. Said tank **2** is used for storing the compressed-air generated by said expander/compressor unit **25** acting as a compressor during the deceleration cycle or in an emergency refilling; and therefore its air pressure is normally set below the initial air pressure of said tank **1**, due to the limitation in the maximum air pressure that can be obtained by the expander/compressor unit **25** acting as a compressor. Like said tank **1**, said tank **2** has a relief valve **11**, a pressure gauge **9**, and electrical heater **16**, and a thermometer **18** for the control of the inside air pressure and temperature.

The power required for both electrical heaters **15** and **16** is supplied by the battery **19**, which is constantly recharged by the alternator **21** of the flywheel/motor/alternator unit **31**, comprising A.C. motor **20**, alternator **21** and flywheel **22**.

The flywheel/motor/alternator unit **31** has several different functions. It can be energized by the use of the A.C. motor **20** of said unit, or regenerated by the use of the shaft power transmitted from the drive train/differential unit **28** through the clutch/gear unit **23** to flywheel **22** during the vehicle deceleration cycle, in order to store the energy needed for providing the peak powers required during the vehicle acceleration cycle. It will run the alternator **21** to charge the battery **19**, which is the electrical power source for all the electrical devices, instruments and controls that run on electrical power. The flywheel/motor/alternator unit **31** can be driven by the A.C. motor **20**, transmitting the shaft power to the expander/compressor unit **25** acting as a compressor in order to refill one or both of the air tanks **1** and **2** through their air inlets **4** and/or **5**, with the valves **6**, **7**, and **24** properly regulated.

The two air tanks **1** and **2** maybe provided with the openings **12** and **14**, and the valve **13** to make possible the transfer of compressed-air from one tank to another when desirable.

The vehicle control system **32** contains all the electrical, mechanical, and manual controls needed to operate the vehicle; and it receives the needed electrical power supply from the battery **19**. While the pressure, temperature and flow rate of the compressed-air may preferably be controlled automatically, the flywheel/motor/alternator unit **31**, the clutch/gear unit **23**, the expander/compressor unit **25**, and the drive train/differential unit **28** may be controlled automatically or manually, depending on the specific application.

It is important to note that the braking energy recovery systems provided by this invention will not only regenerate and store the power supply but also reduce or eliminate the need of a friction-braking system, which is normally used in conjunction with the conventional vehicle drive.

FIG. **2** illustrates in block diagram form, a typical installation of the hybrid flywheel/compressed-fluid propulsion system for nonstationary applications including vehicle drive, according to this invention. The installation consists of five component systems, each of which has functions of a specifc category. The compressed-fluid tank system **41** has high-pressure tanks and all the subsystems needed to regulate the pressure, temperature, and flow-rate of said compressed-fluid into and out of the expander/compresssor system **42**. The expander/compressor to be used may be of the axial-flow type, the radial-flow type, the centrifugal type, or the reciprocating type. It may have a single stage or multiple stages having more than one inlet and outlet. If desirable, it may include a separate compressor unit for compressing the atmospheric air for recovering the braking energy or energency refilling of said tanks. Said system **42** is provided with all the necessary means for controlling the flow and pressure of the fluid being expanded or compressed. It has a mechanical linkage with the drive train/differential system **43** for transmitting the shaft-power through said system **43** to the object to be driven, such as drive trains in case of a vehicle. The flywheel/motor/alternator system **44** normally includes a clutch and gears for transmitting the shaft-power between said systems **44** and said expander/com-

pressor system **42** or said drive train/differential system **43**, at a desired speed ratio. System **44** normally includes an A.C. motor for driving the flywheel in an emergency refilling of the compressed-fluid tanks. It also contains an alternator to generate the electrical power required for operating all the electrical devices, instruments and controls used in the specific nonstationary application. The mechanical linkage between the flywheel/motor-/alternator system **44** and the drive train/differential system **43** can be made or disconnected through the use of said clutch included in the system **44**. In this way, the flywheel can perform anyone of its several functions, as already described above in reference to FIG. **1**. The control system **45** contains all the necessary automatic and manual controls that are needed for the specific nonstationary application. The types of devices, instruments, controls, and other subsystem components which will perform the purported functions of systems **41, 42, 43, 44**, and **45** are well known in the art and may easily be provided.

Since the use of a flywheel as a means for energy storage and shaft drive is not as common as that of a compressed-air turbine, which has been in use by various industries as long as air compressors have been known, it should be instructive to briefly discuss various important aspects of the design and operation of flywheels applicable to this invention.

While the energy stored in a flywheel is proportional to the square of the rotational speed, the theoretical maximum specific energy (E/W)max of a flywheel is determined by the strength/density ratio of the material from which it is made. The following relationship may be used for the weight specific energy:

$$(E/W)_{max}(\text{kw-hr/lb}) = 0.0314\ \text{Kw}\Sigma(\text{kpsi})/\delta(\text{lb/in}^3)$$

where Σ and δ are the stress-level and density of the structural material respectively, and the numerical factor derives from the choice of units used. Kw is a constant which indicates the efficiency with which the particular design utilizes the material's strength, and is a maximum if the stress is distributed uniformly throughout. Therefore, in an optimum design for isotropic material, both radial and tangential stresses would be equal and uniform, and Kw approaches a valve of 1. In a realistic design, the energy per unit weight must be sacrificed somewhat in order to reduce the space required, and with it the weight and cost of the safety shield and gas or vacuum enclosure. The theoretical maximum specific energy of a flywheel may also be expressed as the maximum energy stored, per unit volume of the cylinder enclosing the flywheel's maximum axial height and its maximum radial dimension. The volumetric specific energy may be given by:

$$(E/V)_{max}(\text{kw-hr/ft}^3) = 0.0542\ \text{Kv}\Sigma(\text{kpsi})$$

where the numerical factor derives from the choice of units used, and Kv is the efficiency with which the particular design fills the cylindrical volume as well as utilizing the material's strength; for a uniform-density material, it equals Kw times the fraction of cylindrical volume occupied by the flywheel.

As discussed above, the capacity of a flywheel system as an energy storage medium is dependent on the strength/density ratio and the strength of the structural material of the flywheel. The stress level that can actually be utilized in the structural material is lower than the highest values obtained in the laborato[illegible]due to structural flaws which might be present in the material used and/or flaws which have grown as a result of cyclic loading and/or high-cycle fatigue of the flywheel. Thus, the usable stress level and the resulting energy storage density will depend not only on the design and the material selected, but also on the homogeneity of the properties of the structural material used. Structural materials used in flywheels may be classified into the two categories, isotropic materials and unidirectional composite materials. The most commonly used materials are: metals, alloys, glass, graphite, plastics, fiber-reinforced composites, etc.

A complete flywheel system consists of various subsystem components other than the flywheel itself. The principle subsystem components are: the housing, bearings, seals, vacuum pump (to minimize windage losses), and containing ring (if required).

Part of the kinetic energy stored in a flywheel will in general be nonrecoverable, either due to internal losses or as a result of constraints imposed by other parts of the system. Sources of the internal losses include windage, bearings and seal friction, vacuum pump power requirement, and inefficiencies in both motor and gear systems (if used). The system constraints normally include the maximum rotational speed obtainable and the minimum rotational speed at which the required power can be delivered as a result of the limitation in the maximum permissible torque due to shear stresses in the flywheel system. The internal losses are the source of idling losses of a flywheel system. Both the idling losses and the system constraints will affect the rotational speed, which in turn determines the power levels of the flywheel system. The results of studies made by this inventor as well as other workers indicates that the power levels and service life of flywheels may far exceed those of common battery systems.

Many historical as well as modern applications of flywheels were reviewed by several workers including: R. C. Clark, Trans. SAE 72, 508, (1964); D. W. Rabenhorst, Preprints, ACS Division of Fuel Chemistry, 19 (6), 162–171 (Sept. 1974); and D. W. Rabenhorst and R. I. Taylor, Johns Hopkins Report TG 1229 (Dec. 1973). Many reports of studies made on various important aspects of flywheels can be easily found in the literature.

Thus, a hybrid flywheel/compressed-fluid powered, regenerative, quick-recharging, nonpolluting propulsion system for nonstationary applications, such as vehicle drive, which can use the unlimited supply of air as the working fluid and requires no fuels has been shown. The hybrid propulsion system has the effects and performance characteristics that are quite different from those of the conventional flywheel power system or of the conventional compressed-air power system, as may be ovbious from the above discussion. Although a preferable embodiment using air as the working fluid for application to vehicle drive has been disclosed fully, it will be obvious to those skilled in the art that various modifications and other applications may be made without departing from the spirit of the invention, as exemplified by the typical application shown in FIG. **2**. Today, various improved and light materials, such as fiber-reinforced composite materials, are available for the construction of high-pressure tanks and flywheels having high-performance characterisitics. With these improved materials, high-pressure tanks and flywheels can be designed and constructed economically to withstand working stresses over several hundred thousand pounds

per square inch, and flywheels can be constructed to provide service cycles as many as nearly a million cycles. High-pressure compressors can be installed easily in service stations and parking lots across the country to provide a quick-refilling of the compressed-air tanks used in vehicles driven by the invention, as often as needed. To assist the invention in long-range crusing, a small combustion-engine powered compressor may be carried or installed in the vehicle in order to refill the compressed-air tanks wherever and whenever needed. The compressed-fluid, such as compressed-air, carried in the vehicle can be partly used for generating cold and hot air streams by using a vortex-tube, for cooling or heating the interior of the vehicle for the comfort of passengers. Today, vehicles can be designed and built to utilize lighter materials, achieve lower aerodynamic drag losses by reducing frontal area and drag coefficient, reduce spinlosses by using more efficient bearings and gears, and lower rolling resistance by using radial tires. Needless to say, all of these factors have the effect of improving vehicle range for a fixed charge of compressed-air.

It should be noted that the present invention is intended for and adaptable to all nonstationary applications. It may use any nonpolluting fluid as the energy-storage medium, any type of expander or compressor for generating and regenerating shaft power, and any type of flywheel for storing and regenerating shaft power. It may also be used in conjunction with another propulsion system, if desirable. It is the combination of a compressed-fluid power system and a regenerative flywheel power system, which produces the desirable effects and characteristics that are absent from the conventional compressed-fluid power system alone or the conventional flywheel power system alone, that is the heart of the present invention.

The invention claimed is:

1. A hybrid flywheel/compressed-fluid propulsion system for a self-propelled object, said system comprising:

(A) a rotatable drive shaft adapted to propel said object when rotated;

(B) energy conversion means connected to said drive shaft and employing a compressible working fluid, said energy conversion means being adapted, when supplied with said working fluid in a compressed state, to expand said working fluid and produce shaft work for transmission through said drive shaft;

(C) a primary container for storing said compressible working fluid in compressed state;

(D) first conduit means adapted to connect said primary container and said energy conversion means, and to supply compressed working fluid to said energy conversion means;

(E) first valve means interrrupting said first conduit means and adapted to selectively control the flow of compressed working fluid to said conversion means; and

(F) a flywheel connected to said drive shaft through disconnecting means adapted to selectively connect said disconnect, independent of said conversion means, said flywheel from said drive shaft.

2. Propulsion system according to claim 1 and additionally comprising separate drive means adapted to selectively and independently drive said flywheel.

3. Propulsion system according to claim 1 additionally comprising a generator connected to said flywheel and adapted to generate electrical power when rotated, and a rechargeable battery for storing the electrical energy so generated.

4. Propulsion system according to claim 1 wherein said energy conversion means also is adapted, when driven by said drive shaft and supplied with said working fluid in noncompressed state, to compress said working fluid through conversion of shaft work transmitted by said drive shaft into work of compression.

5. Propulsion system according to claim 4 and additionally comprising:

(A) a secondary container for storing said working fluid in compressed state;

(B) second conduit means adapted to connect said secondary container and said energy conversion means, and to transmit compressed working fluid between said energy conversion means and said secondary container;

(C) second valve means interrupting said second conduit means and adapted to selectively control the flow of compressed working fluid therethrough; and

(D) third valve means adapted to selectively connect said first conduit means and said second conduit means to said conversion means.

6. Propulsion system according to claim 1 or 5 and additionally comprising means for heating and controlling the temperature of said working fluid inside of said container.

* * * * *

United States Patent

Minkus

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[45] Sept. 26, 1972

[54] **ANTI-POLLUTION REGENERATIVE ENGINE**

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[73] Assignee: **Albert M. Sheppard,** Chicago, Ill. part interest

[22] Filed: **Jan. 29, 1971**

[21] Appl. No.: **108,064**

[52] **U.S. Cl.** .....**60/57 R,** 60/59 R, 92/147

[51] **Int. Cl.**.....**F01b 1/00**

[58] **Field of Search** .....60/57 R, 59 R, 62; 91/412; 92/147, 149

[56] **References Cited**

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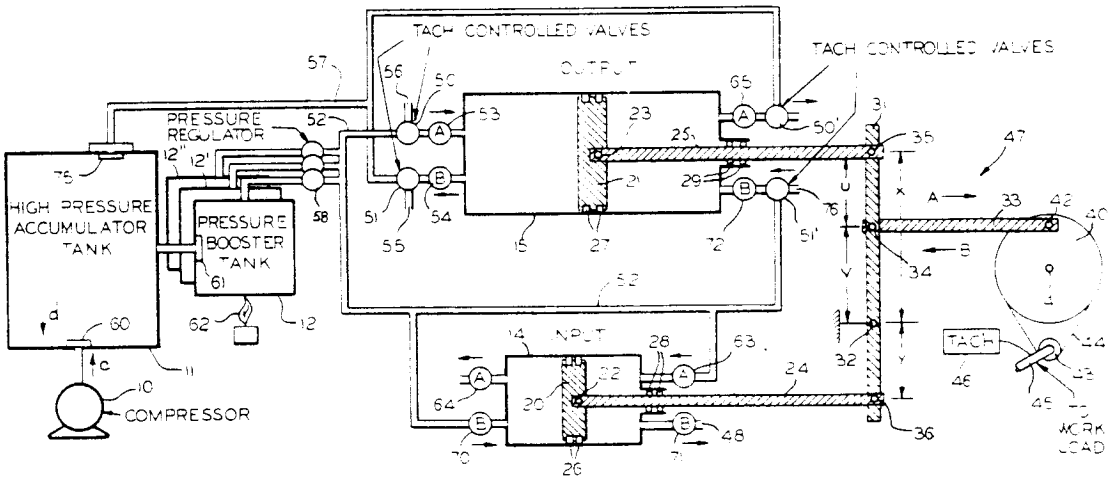
[57] **ABSTRACT**

Air motor cylinders are paired, with one cylinder having a greater volume than the other. Lever arms attached to two pistons in these cylinders have a length differential which compensates for the volume differential so that both pistons perform the same amount of work on a load device. Attached to a drive shaft for driving the load device is a tachometer which indicates when the load is applied or removed. When the tachometer indicates that the load has slackened, valves operate so that one of the cylinders ceases to act as a driving force and acts, instead, as a compressor, thereby returning air to a compressed air tank. Thus, during a slack load conditions, the compression cylinder stores energy to drive the system during high load conditions.

11 Claims, 2 Drawing Figures



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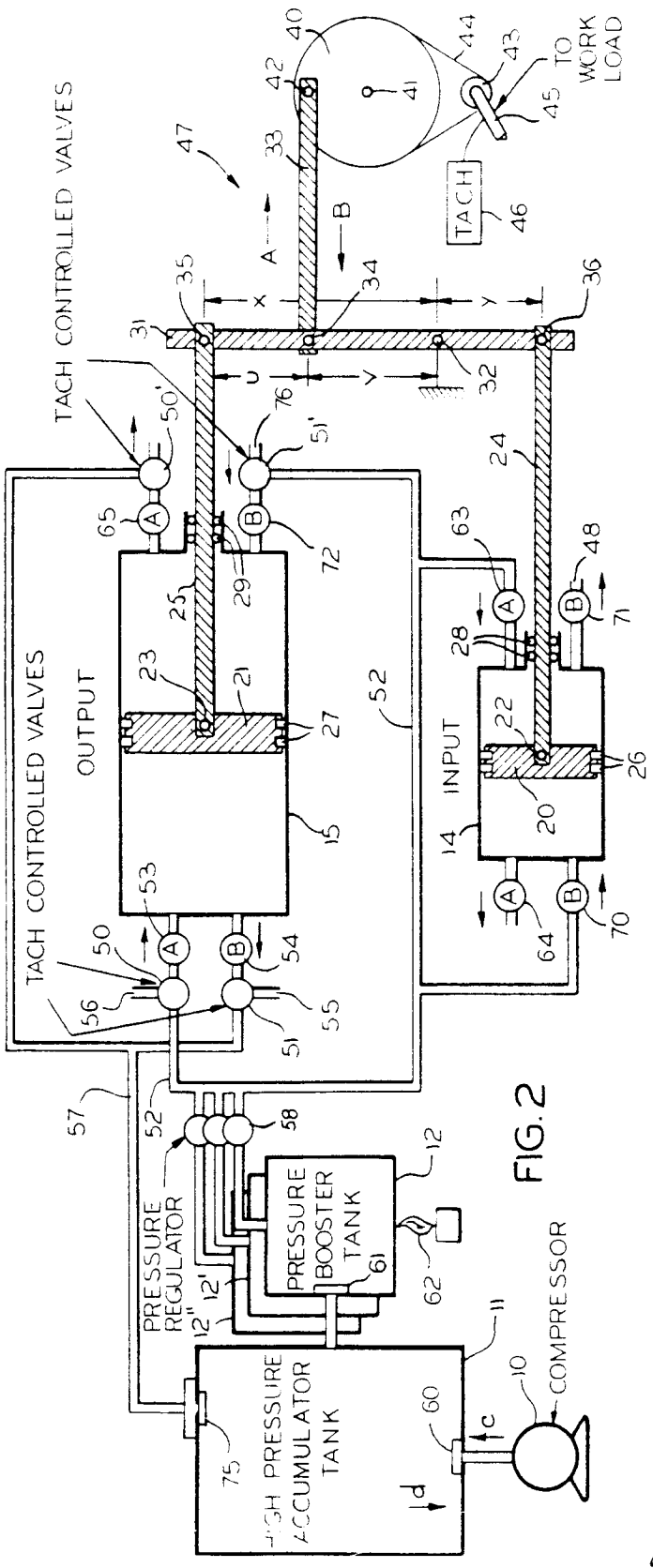

FIG. 2

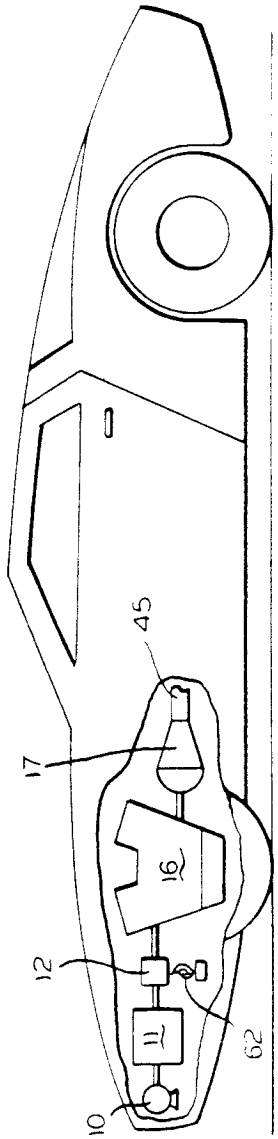

FIG. 1

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ANTI-POLLUTION REGENERATIVE ENGINE

This invention relates to anti-pollution engines and more particularly to push-pull hot air motors with a regenerative compressed air feed during unloaded or negative load conditions.

Primarily the invention contemplates a clean air motor or engine for an automobile; however, the motor has universal use for driving any suitable load device. In greater detail, the present day internal combustion engine is blamed for air pollution, especially in densely populated centers, such as large cities. Accordingly, there is a need for a clean air motor which will propel an automobile without contributing to further pollution. While it is desirable for such a motor to propel the automobiles at great speeds, this is not necessarily a primary objective. Quite the contrary, the air pollution problems are most severe in the more densely populated centers where low speeds of 35 mph., or less, are more than adequate.

One form of motor which should be ideal for solving air pollution problems, for city driving, is run by heated compressed air. Air motors are compact, lightweight sources of smooth, vibrationless power, and they cannot be harmed by overloading. In common with most fluid motors, they have high torque and power, per pound of weight. There is no significant heat build-up when air motors are stalled for considerable lengths of time. Air motors may stop and start instantly and provide an infinitely variable control of torque and speed. However, as with most machinery, there are many advantages if these motors are designed to run continuously and under substantially uniform load.

These air motors cannot directly convert energy released by an unregulated expansion of compressed air into a mechanical converter since the cooling effect, obtained when air or gas expands, limits the amount of expansion that can be used effectively. If air were expanded through an air motor at a high ratio of initial compression to final expansion, there would be a freezing of moisture in the air motor. Therefore, the air motor is designed to use air at a regulated line pressure working on a piston head.

These piston-type air motors may have any suitable number of cylinders, arranged in any suitable positions, such as a V-8 configuration, for example. Output torque is developed by pressure working on a piston confined within each of these cylinders. More power is obtained by using a motor with a higher speed revolution, larger piston diameter, more pistons, or increased stroke.

Accordingly, it is apparent that air motors are ideally suited to driving automobiles. Since these motors can lug heavy loads at all speeds, they are particularly adaptable to slow-speed operation, and especially to driving automobiles at low city speeds. However, there are practical problems since the compressed air tanks would be prohibitively large to drive the auto for even a short distance, and increased compression ratios do not solve the problems. On the other hand, much of city driving is stop and go, pulling and coasting, etc. Therefore, if the automobile's primary motive power source is used to store compressed air at all times when the power source is not pulling the automobile, the compressed air tank can be made much smaller.

Accordingly, an object of the invention is to provide a clean air, pollution-free automobile by taking advantage of all of these and other desirable features of air motors. In particular, an object is to provide an air motor which runs at constant speeds and under uniform loading, despite widely fluctuating load conditions. Here an object is to maintain a uniform dynamic inertia, despite widely fluctuating load conditions.

Another object is to provide an air motor which automatically returns energy to the system during unloaded, lightly loaded, or even negatively loaded conditions. In this connection, an object is to almost instantly perform substantial work functions and to run smoothly when the work load is removed.

Yet another object of the invention is to provide an automobile driven by compressed air. Here an object is to provide an automobile with an air motor which delivers a full power output at all times, with the excess power being used to store energy, by compressing air, during periods while the automobile is not otherwise drawing full power. In particular, an object is to provide an automobile especially well suited for stop and go driving in crowded city streets.

In keeping with an aspect of the invention, air motor cylinders are paired with a piston in one cylinder having a shorter stroke than the piston in the other cylinder. Lever arms attached to the two pistons have a length differential which compensates for the stroke differential, so that both pistons perform the same amount of work on a load device. A tachometer attached to a shaft driving the load indicates when the load is applied or removed. When the tachometer indicates that the load has slackened, valves operate so that one of the cylinders ceases to act as a driving cylinder and acts, instead, as a compressor, thereby returning air to a compressed air tank. Thus, during slack load conditions, the compression cylinder stores energy to drive the system during high load conditions.

For example, if the air motor is used as the prime driving source for an automobile which runs up hills and down hills, the compressed air is expended to drive the automobile uphill. As the automobile runs down hill, its falling weight rotates the air motor and thereby stores compressed air. Thus, the work performed by the falling weight of the automobile is stored, as energy, in the form of compressed air. Likewise, each time that the automobile stops, the motor continues to run, and power is stored to drive the automobile when it starts again. Thus, the air motor runs smoothly, as if it were exposed to a uniform and unvarying load regardless of whether the automobile is running uphill, downhill, through traffic, or when stopped at a traffic light.

The nature of a preferred embodiment of the invention for accomplishing these and other objects may be understood best from a study of the following description and the attached drawing in which:

FIG. 1 schematically shows an automobile driven by the inventive compressed air system, with part of the hood broken away to show such system in the schematic form of a block diagram, and

FIG. 2 schematically shows a pair of air cylinders, and the controls for an associated compressed air line, required to realize the invention.

Briefly, FIG. 1 shows an automobile with the hood area partially broken away to show the inventive source of motive power. This source includes a relatively small compressor 10 which may be driven by any suitable

small engine to store compressed air in air accumulation tank **11**. One or more booster tanks **12** increase air pressure by a relatively non-polluting means, such as being heated by a heat source **62**. The air in the boosted pressure tank **12** drives an air motor **16** which includes a number of paired pistons, here shown in an exemplary V-configuration. The air motor **16** is connected to a transmission **17** of a conventional type. Except for this power source, the automobile of FIG. **1** is conventional.

FIG. **2** shows the mechanical parts of the air system in heavily inked lines; the moving pistons, shafts, and levers are shown by crosshatching; and the air line is shown by parallel lines. More particularly, the air system includes the compressor, the high pressure accumulator tank **11**, and the booster tank **12**. Three tanks **12**, **12'** and **12''** are here shown so that one tank is always being pressurized, one pressurized tank is on stand-by, and one tank is being exhausted. The air motor includes a pair of air cylinders **14**, **15** — having short and long strokes respectively. The short stroke cylinder **14** is a driving or input device which always furnishes motive power for the total system. The long stroke or output cylinder **15** may either supplement the cylinder **14** by providing a driving force; or it may also serve as a compressor and act as a load by returning compressed air to the high pressure accumulation tank **11**, during periods when the automobile is not using full motor power.

The moving parts of the system include a pair of pistons **20** and **21**, in the short stroke cylinder **14** and the long stroke cylinder **15**, respectively. Wrist pins **22**, **23** pivotally attach first and second connecting rods **24**, **25** to the pistons **20**, **21**, respectively. Any suitable packing means, such as piston rings or Teflon O-rings, **26**, **27**, seal the pistons **20**, **21** to the walls of the cylinders **14**, **15**, respectively. Likewise, similar packing means **28**, **29** seal the rods **24**, **25**, respectively, to sleeves in the cylinders **26**, **27**. While the drawing shows only two cylinders **14**, **15**, it should be understood that any suitable number (such as four, six, or eight) could be provided in a straight line, a V-configuration, or a radial arrangement. In automobiles, the V-configuration is preferred.

The connecting rods **24**, **25** are interconnected by a rocker arm **31**, pivoted at a fixed or ground point **32**. The useful work load is taken from a third connecting rod **33** which is attached to the rocker arm **31** at the point **34**. The length of the rocker arm **31** is divided into two parts. One rocker arm part X is measured from ground point **32** to the connecting rod **25** pivot point **35**. The other rocker arm part Y extends from the ground point **32** to the connecting rod **24** pivot point **36**.

The longer part X of the rocker arm **31** is divided into two parts U and V. The part U extends between the load take off point **34** and the connecting rod **25** point **35**. The other part V extends between the load take off point **34** and the ground point **32**. The relative lengths of the lever arms U, V, X, and Y are selected with respect to the lengths of the two piston strokes so that both cylinders contribute essentially the same driving force to the connecting rod **33**.

... the larger size motors with many cylinders, the construction is more nearly like the construction of conventional automobile engines with conventional piston rings, crank cases, and compression appears on only one side of the piston. If the air motor is a large and complex one, somewhat similar in construction to an automobile engine, the same lever arm differential (X–Y) may be provided by using a crank shaft having throws of different lengths. Of course, care is taken to maintain a dynamic engine balance.

While the foregoing description speaks of the air motor as the prime mover for driving an automobile, the exact nature of the load is not too relevant. However, for a schematic disclosure, the load device is here shown as a driven fly wheel **40** rotating about an axle **41** responsive to the reciprocating motion of connecting rod **33** acting upon a pin **42** near the rim of the wheel **40**. The fly wheel axle **41** could impart motion directly; or, a suitable speed reduction gearing (e.g., transmission **17**) may be provided. As here shown, for schematic purposes, the speed reduction is accomplished by providing a small pulley wheel **43** driven by a belt **44**. The drive shaft **45** rotates responsive to the power applied to the pulley **43**.

A tachometer **46** detects the varying load conditions experienced by the shaft **45**. Thus, when a load is applied to the shaft **45**, there is a slight tendency for the shaft to slow, and the tachometer **46** so indicates. In the above-slated analogy, this is somewhat like a driven automobile going uphill. On the other hand, if the load is removed, or tends to become negative, the shaft **45** tends to speed up, and the tachometer **46** so indicates. For example, there is no load if the automobile stops at a traffic light; or, shaft **45** experiences a negative load if the automobile runs downhill.

The letters A and B are used to indicate the two reciprocating motions of the connecting rod **33**, as indicated in the drawing near the reference character **47**. These two letters A and B are also used in circles elsewhere in the drawing to identify valves which open and close responsive to the movement of shaft **33**. Thus, all A valves open (and all B valves close) when the shaft **33** moves in the direction A. Conversely, all B valves open (and all A valves close) when the shaft **33** moves in the direction B.

Vents to the atmosphere are shown by two short, open end lines, as at **48**, for example.

On the cylinder **15**, a pair of valves, **50**, **51** and **50'**, **51'** are controlled responsive to signals from the tachometer **46**. Thus, when the shaft **45** is running under a substantial load, the tachometer signal sets the valves **50**, **51** to extend the air line **52** to the A valve **53**, and the B valve **54** to the atmosphere vent, respectively. When the shaft **45** is running under a reduced load, no load, or a negative load, the tachometer signal sets the valves **50**, **51** to connect the A valve **53** to the atmosphere vent **56** and the B valve **54** to the air line **57**, respectively. Similar results occur at the valves **50'** and **51**

A pressure regulator **58** may take any suitable form. Its chief function is to admit a predetermined amount of air pressure to the air line **52**, regardless of the pressure in the booster tanks **12** (assuming that the tank pressure is at least high enough to maintain the line pressure). Thus, the expansion of air in the cylinders **14**, **15** is always constant and below the level which might cause ice to form.

A number of pressure actuated valves are shown in the drawing by small rectangles, such as **60**. For example, if the air pressure from compressor **10** exceeds air pressure in tank **11**, the valve **60** opens and air passes from the compressor **10** into the tank **11**. However, if pressure **11** is the greater, valve **60** is closed, and air cannot pass from the tank **11** to the compressor **10**.

With the foregoing description of the apparatus and components in mind, it is thought that the invention will best be understood by the following step-by-step description of the work cycle.

First, the compressor **10** fills tank **11** to the maximum supplied pressure. Thereafter, the compressor **10** operates on demand. Whenever the line pressure c drops, the compressor **10** starts and repressurizes the tank **11**. Thus, the tank **11** rarely falls below a predetermined pressure.

THe air in tank **11** passes through valve **61** to fill a first of the booster tanks **12**. A flame **62** symbolically indicates that energy is added to further increase the air pressure at this point in the system. Thus, there is an air pressure differential between tanks **11** and **12**. To insure a constant supply of air at such a boosted pressure, a plurality of booster tanks **12** may be provided with one tank **12** being pressurized while another tank **12'** is being exhausted, and a fully pressurized tank **12''** is standing by. While the flame **62** implies that pressure is increased by heating the compressed air, the invention is broad enough to cover any suitable pressure booster system. The tank **11** is fairly large to enable storage of a sufficient amount of air, which is subject to pressure fluctuation. The three booster tanks **12** are fairly small, and enough energy is provided at **62** to avoid substantially all pressure fluctuation. The pressure regulators **58** further attenuate any pressure fluctuations which might otherwise occur in the line **52**. Thus, the air line **52** is supplied with a well regulated air pressure.

Next, assume that the connecting rod **33** is moved in direction A. All of the A valves open, and all of the B valves close. Air from line **52** passes through the A valve **63** to drive the piston **20** to the left, as viewed in FIG. **2**. The moving piston **20** pushes air out the A valve **64** and into the atmosphere. Also, air in line **52** passes through valves **50**, **53** to drive the piston **21** to the right, as viewed in FIG. **2**. Air is pushed out of cylinder **15** via the valves **65** and **50'**.

The rod **24** slides to the left, the rod **25** slides to the right, and rocker arm **31** rocks in a clockwise direction about the ground point **32**. The connecting rod **33** moves to the right, and wheel **40** turns in a clockwise direction.

When the rod **33** reaches the end of its rightward stroke, the A valves close, and the B valves open. The valves operate in any well known manner such as through the use of pressure differentials or through the use of lifter arms operated by cams. The B valve **70** admits air from line **52** to push the piston **20** to the right, as viewed in FIG. **2**. The moving piston **20** pushes air out the B valve **71**, and into the atmosphere at vent **48**. The air in line **52** is admitted via valve **72** to push the piston **21** to the left. Air is pushed out valves **54** and **51** to the atmosphere at vent **55**. The rod **24** moves to the right, rod **25** moves to the left, and rocker arm **31** rocks in a counterclockwise direction. Connector rod **33** moves to the left in direction B, and wheel **40** continues to rotate in a clockwise direction.

As it turns, the fly wheel **40** imparts power through belt **44** to pulley **43** and shaft **45**, or through transmission **17** (FIG. **1**) to shaft **45**.

If the shaft **45** is under load (as when an automobile is moving uphill), the tachometer **46** gives a signal, and the system continues to operate in the described manner. Both pistons **20**, **21** contribute approximately the same work force to the motive system, owing to the differentials of lever arm lengths, piston strokes, and the like.

Next, assume that the shaft **45** encounters a slight load, no load (as when an automobile stops) or a negative load (as when the automobile is moving downhill). The tachometer gives a signal which resets the valves **50**, **51**, **50'**, and **51'**. This valve operation disconnects the line **52** from cylinder **15**, and connects line **57** thereto. The air vents **56** and **76** are opened by valves **50**, **51'**.

The drive or input cylinder **14** continues to work, as before described. When connecting rod **33** moves to the left, the B valves open, and the A valve close. The operation of the valves occurs through the use of the previously mentioned well known means. Air is compressed through valves **54**, **51**, line **57**, valve **75**, and into tank **11**. The back pressure on the left side of the piston **21** is relieved by air entering at vent **76** and passing through valves **51'**, **72**.

Upon reflection, it should be obvious that the system runs under substantially a full and uniform load. When power is taken from shaft **45**, both cylinders apply power to the work load. When less or no power is taken from shaft **45** — or when the load actually drives the shaft — the compression of air within the cylinder **15** is used to repressurize the tank **11**. Therefore, the mechanical parts of the system experience a fairly uniform loading regardless of the demands placed upon the system.

The system is regenerative in that the compressed air taken from the system during heavy loading is returned — at least in part — to the system by the compressor action within cylinder **15** during periods of light loading. Moreover, since the average air pressure in the booster tanks **12** is higher than the air pressure in accumulator tank **11**, there is a greater potential acting on the input or drive cylinder **14** than is resisting the output of compression cylinder **15**. Accordingly, the stroke in cylinder **15** is made larger so that a greater amount of air is compressed and forced into tank **11**. The relative lengths of the piston strokes are selected with due regard to the potential resulting from the pressure differential between tanks **11** and **12** and the frictional losses in the system. Thus, if the shaft **45** is unloaded for an extended period of time, the output cylinder **15** is able to compress air into the tank **11** up to the limits set by any safety valve and by the energy supplied at **62** or by a negative loading acting on the shaft **45**. In theory, at least, there is no reason why the work done by, say an automobile running downhill for a predetermined distance, could not provide most of the energy required to bring tank **11** up to substantially full pressure. Or in traffic conditions with stop and go driving, the automobile motor stores energy during light loading to help drive the automobile during periods of heavy loading.

From the foregoing, it should be apparent that the invention has particular value when a widely fluctuating

load condition is experienced as in stop and go city driving. Moreover, further sophistication allows room for degrees of adjustment. For example, if there are six cylinders in the motor **16**, one cylinder **15** could be switched to compression for a slight reduction in shaft loading, two cylinders **15** could be switched for medium load reduction, and three cylinders **15** could be switched for maximum load reduction. Moreover, the foregoing speaks in terms of differential strokes and lever arms. Similar effects may be produced by differential cylinder bores or capacities. The terms "long stroke" and "short stroke " are to be construed to have a meaning broad enough to cover equivalent modifications of bore, or capacity.

Still other modifications will readily occur to those skilled in the art. Therefore, the appended claims are to be construed to cover all equivalent structures which may fall within the spirit and the scope of the invention.

I claim:

1. An air motor comprising means including a tank for accumulating compressed air under a predetermined pressure,

first cylinder means having a piston with a relatively short stroke and a second cylinder means having a piston with a relatively long stroke.

means responsive to the air pressure in said accumulating tank for driving at least one of said pistons in at least one of said cylinders,

means responsive to power from the piston in said one of said cylinders for driving the other of said pistons in the other of said cylinders, and

means comprising said driven piston in the other cylinder for compressing air in said accumulating tank.

2. The air motor of claim **1** and means for boosting the air pressure between said accumulating tank and said one piston, thereby creating a work potential responsive to a differential of air pressure between the input of said piston and said accumulating tank.

3. The air motor of claim **1** and means for normally coupling said first and second cylinders for the associated pistons to be driven responsive to the air pressure in said tank, and

means for normally interconnecting said two pistons to apply work to a load device.

4. The air motor of claim **3** and detector means associated with said work load for detecting when there is a reduction in said work load, and

means responsive to said detection of said work load reduction for switching the coupling to cause said driven piston to supply said compressed air to said tank, whereby said motor tends to run under fairly constant loads.

5. The air motor of claim **3** wherein said interconnecting means comprises a plurality of lever arms having relative lengths which are related to the difference between said strokes so that each of said pistons does substantially the same work with respect to said load device.

6. The air motor of claim **5** wherein said lever arms are coupled to rotate a shaft, and

said detector means comprises a tachometer for detecting when said shaft speeds up or slows down, and

means responsive to said tachometer for switching the cylinder having the other of said pistons between a driven mode and a compressing mode of operation.

7. The air motor of claim **6** and pressure regulator means interposed between said tank and said cylinders.

8. The air motor of claim **7** and pressure booster tank means interposed between said pressure regulator and said tank.

9. The air motor of claim **8** wherein there are at least two of said pressure booster tank means and means for pressurizing one of said booster tanks while the other of said booster tanks is being exhausted.

10. The air motor of claim **3** and means for coupling said interconnecting means to drive an automobile transmission.

11. The air motor of claim **10** and means responsive to the weight of an automobile rolling downhill for coupling said other cylinder to apply compressed air to said tank.

* * * * *

Street Railway Journal, May 1886

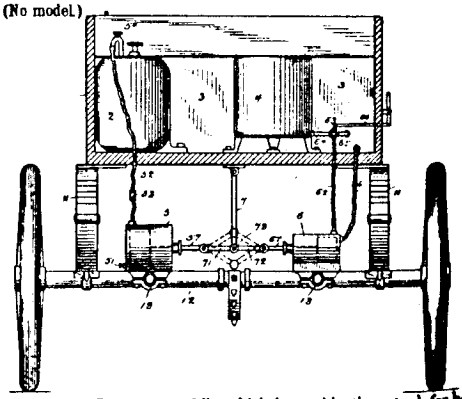
New Compressed Air Motor.

A Pittsburg mechanic claims to have invented a compressed air motor for street car travel, an entirely new and economical principle. The front wheels are unusually large, and there are small air pumps, three inches stroke by three diameter, set in the periphery of the wheels. The force of the air pump is exerted by the weight of the car over the wheel, calculated at 1,000 pounds to each wheel. The air thus compressed passes into the hollow hub of the wheel, whence it carries its force into the receiver.

U. S. PATENT

OCTOBER 22, 1901.

684,953. PUMPING DEVICE FOR AUTOMOBILES. WILLIAM F. SINGER, New York, N. Y. Filed July 16, 1901. Serial No. 68,068. (No model.)



Claim.—1. In an automobile vehicle in combination a tank for holding liquid fuel and air, a water-tank, a boiler, pumps for forcing air into said air-tank and water into said boiler respectively, a toggle-joint connecting the pistons of said pumps, the elbow of said toggle-joints and the pair of said pumps being connected, the one to the body, the other to the running-gear of said vehicle, whereby the relative vertical motion of said body is utilized to reciprocate said pump-pistons, substantially as described.

2. In an automobile vehicle in combination a tank for holding liquid fuel and air, a water-tank, a boiler, pumps for forcing air into said air-tank and water into said boiler respectively, a toggle-joint connecting the pistons of said pumps the elbow of said toggle-joints and the pair of said pumps being connected, the one to the body, the other to the running-gear of said vehicle, whereby the relative vertical motion of said body in either direction is utilized to reciprocate said pump-pistons, substantially as described.

3. In an automobile vehicle in combination a tank for holding liquid fuel and air, an air-pump, means whereby the vertical movement of the body of said vehicle relative to its running-gear is utilized to drive said pump, a pipe leading from said pump to said tank and a pressure-relief valve whereby any excess of air is wasted into the atmosphere, substantially as described.

4. In an automobile vehicle in combination a water-tank, a boiler, a pump, means whereby the vertical movement of the body of said vehicle relative to its running-gear is utilized to drive said pump, an inlet-pipe leading from said tank to said pump, an outlet-pipe leading from said pump both to said boiler and to said tank, and means, as a three-way cock in said pipe, for diverting the flow of water from said pump either to said boiler or to said tank, substantially as described.

5. In an automobile vehicle in combination a water-tank, a boiler, a pump, means whereby the vertical movement of the body of said vehicle relative to its running-gear is utilized to drive said pump, an inlet-pipe leading from said tank to said pump, an outlet-pipe leading from said pump both to said boiler and to said tank, means, as a three-way cock in said pipe, for diverting the flow of water from said pump either to said boiler or to said tank, and manually-operative means for manipulating said water-diverting means, substantially as described.

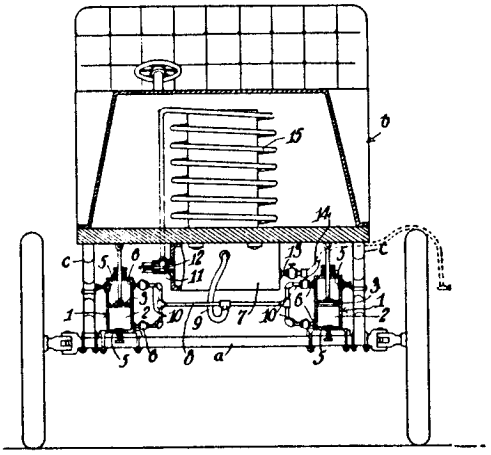
6. In an automobile vehicle in combination a tank for holding liquid fuel and air, a water-tank, a boiler, a pump for forcing air into said air-tank and a pump for forcing water into said boiler, a toggle-joint connecting the pistons of said pumps, the elbow of said toggle-joint and said pair of pumps being connected, the one to the body, the other to the running-gear of said vehicle, means for automatically wasting the excess of air pumped by said first-named pump and separate means for diverting the flow of water from said second-named pump either to said boiler or to said water-tank, substantially as described.

7. In an automobile vehicle in combination a tank for holding liquid fuel and air, a water-tank, a boiler, a pump for forcing air into said air-tank and a pump for forcing water into said boiler, a toggle-joint connecting the pistons of said pumps, the elbow of said toggle-joint and said pair of pumps being connected, the one to the body, the other to the running-gear of said vehicle, means for automatically wasting the excess of air pumped by said first-named pump and separate manually-operative means for diverting the flow of water from said second-named pump either to said boiler or to said water-tank, substantially as described.

8. In an automobile vehicle in combination a tank for holding liquid fuel and air, a water-tank, a boiler, a pump for forcing air into said air-tank, a second pump for forcing water into said boiler, a toggle-joint connecting the pistons of said pumps, the elbow of said toggle-joint and said pair of pumps being connected, the one to the body, the other to the running-gear of said vehicle, said pumps being in line with and facing each other and so spaced apart that their pistons reach the extreme end of their strokes when said toggle-joint is fully extended, substantially as described.

MAY 12, 1908.

887,503. AIR-CUSHION AND AIR-COMPRESSOR FOR AUTOMOBILES AND OTHER VEHICLES. WESLEY H. NELSON and LEE W. GALLOWAY, Norwood, Colo. Filed May 27, 1907. Serial No. 375,950.

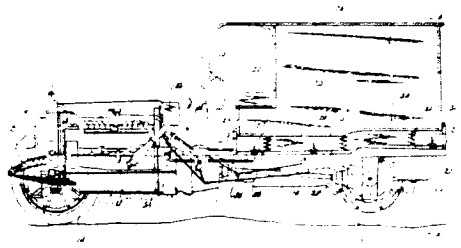


1. A vehicle having an air compressing apparatus comprising a plurality of double-acting air pumps mounted upon the wheel-axle and having the rods of their pistons connected to the bottom of the vehicle, an air reservoir fixed to said vehicle-bottom, an arrangement of pipes having communication with the cylinders of said pumps opening above and below the pistons of said pumps, and means delivering air pressure from said arrangement of pipes to said air-reservoir.

2. A vehicle having an air compressing apparatus comprising a plurality of double-acting air-pumps mounted upon the wheel-axle and having the rods of their pistons connected to the bottom of the vehicle, an air-reservoir fixed to said vehicle-bottom, an arrangement of pipes having communication with the cylinders of said pumps opening above and below the pistons of said pumps, and a pipe-coil having connection with said air-reservoir for utilizing the air-pressure thereof.

APRIL 20, 1920.

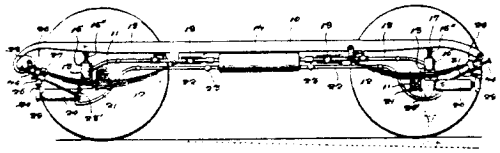
1,337,501. COMPRESSOR. VERONICA ARLUSKES, Bridgeport, Conn. Filed May 28, 1918. Serial No. 237,065. 2 Claims. (Cl. 280—106.5.)



2. In a supplementary power means for self propelled vehicles, the combination with a truck, of a rectangular casing rising from said truck, a car body slidably engaged therein, a chamber formed between the lower portion of said car body and said truck, a plurality of compression springs in said chamber by which said body is supported, air inlet valves entering said chamber, a single outlet valve from said chamber, an air reservoir, and tubular connections between said outlet valve and said air reservoir.

SEPTEMBER 25, 1923

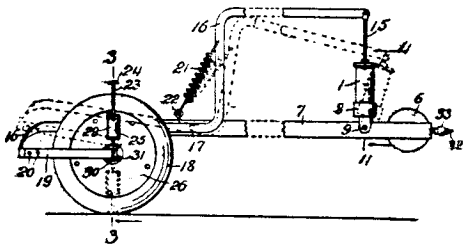
1,469,140. PUMP. EDWARD J. BAISDEN, New York, N. Y. Filed Sept. 8, 1922. Serial No. 586,926. 2 Claims. (Cl. 230—27.)



1. In a vehicle, an air compressor actuated by the expansion and contraction of the springs of the vehicle, a storage tank, means for connecting the same with the compressor, means controlled by the air pressure within the tank for automatically interrupting the flow of air into the tank when the pressure exceeds a certain degree, a jack hingedly connected with a part of the vehicle, manually operated means for connecting the jack with the compressed air tank and means for normally supporting the jack in raised position with its shoe in retracted position.

JUNE 7, 1932

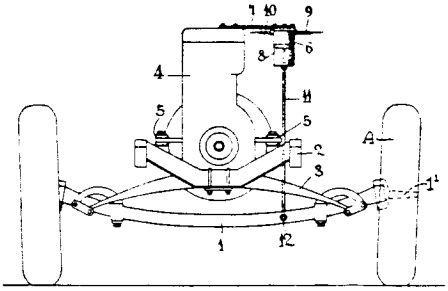
1,862,195. AUTOMATIC PUMPING MECHANISM. RALPH L. NEWTON, Kansas City, Mo. Filed Mar. 12, 1930. Serial No. 435,092. 11 Claims. (Cl. 230—33.)



1. In an automatic pumping mechanism, the combination with a vehicle having a supporting wheel, of a pump carried by said vehicle apart from and not revoluble with said wheel, an actuating member carried by said wheel and arranged, when said wheel travels along the ground to strike the ground and to be moved thereby in one direction, yielding means for retracting said member, a lever fulcrumed on said vehicle and connected to and arranged, when oscillated, to operate said pump and movable by said member in one direction, and means for retracting said lever.

JULY 28, 1936

2,049,010
MOTOR VEHICLE
Erwin C. Horton, Hamburg, N. Y., assignor to Trico Products Corporation, Buffalo, N. Y.
Application April 26, 1935, Serial No. 18,479
8 Claims. (Cl. 180—54)



1. A motor vehicle having an axle, a body frame spring-supported thereon for relative movement, a power plant resiliently supported on the frame for relative movement, and an accessory having two parts movable relative to each other for its actuation, one of said parts being connected to the power plant and the other of said parts being connected to the axle and operable by either or both of the relative movements set up between the axle and the body frame, on the one hand, and between the latter and the power plant, on the other hand.

April 21, 1970 L. H. HOWARD ET AL 3,507,580

ENERGY GENERATOR

Filed May 12, 1967

Fig. 2.

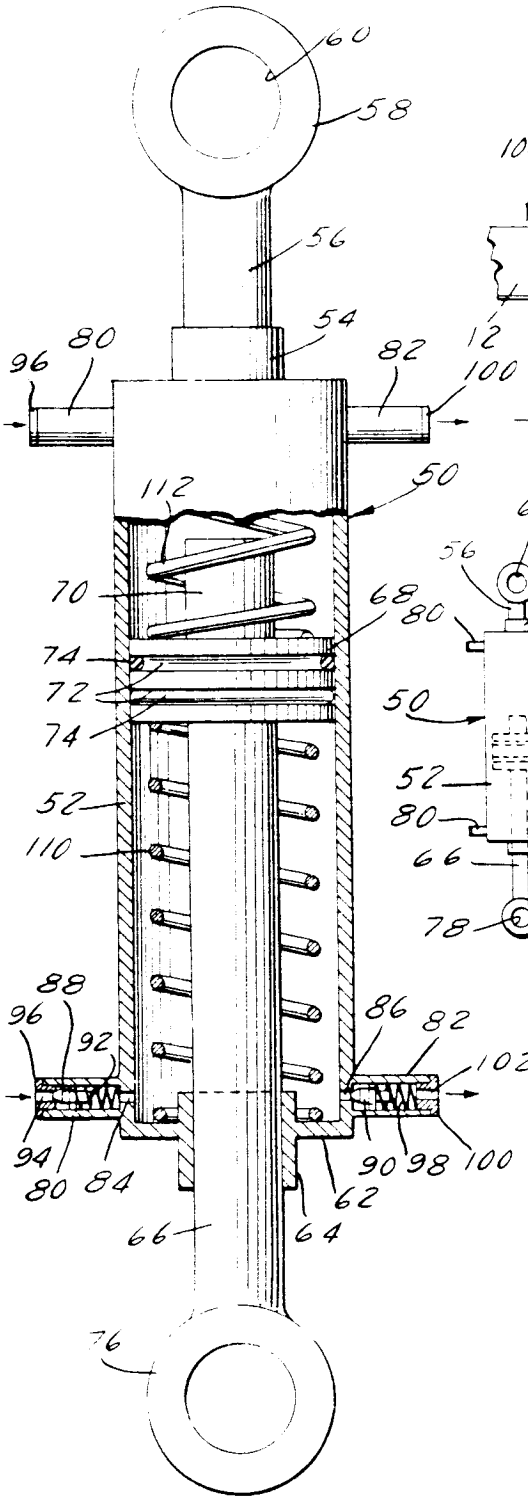


Fig. 1.

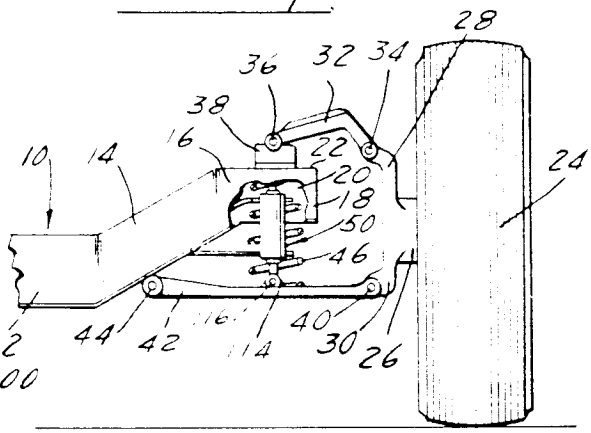
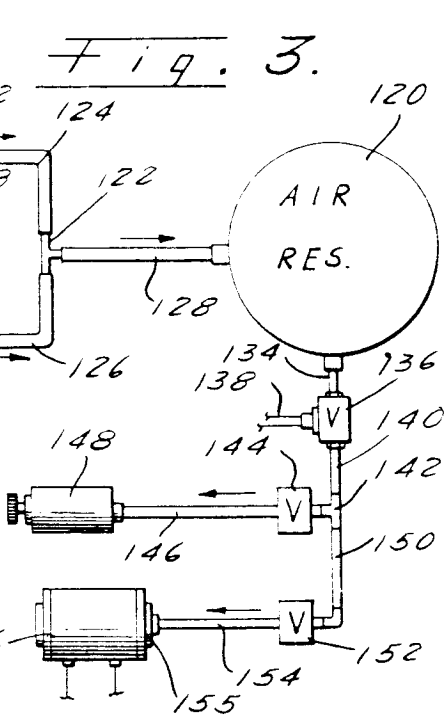


Fig. 3.



London H. Howard,
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INVENTORS.

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United States Patent Office 3,507,580 Patented Apr. 21, 1970

3,507,580

ENERGY GENERATOR

Landon H. Howard, 2841 Monogram Ave. 90815, and Benjamin T. Howland, 3912 Canehill Ave. 90808, both of Long Beach, Calif.

Filed May 12, 1967, Ser. No. 638,115
Int. Cl. F04b 35/02
U.S. Cl. 417—231 1 Claim

ABSTRACT OF THE DISCLOSURE

Energy generating apparatus having relatively movable pump parts operably mountable between vehicle parts having relative vertical movement whereby the pumping apparatus is operated to supply pressure fluid for operating fluid pressure operable means.

BACKGROUND OF THE INVENTION

While the present invention has particular utility on connection with the provision of an auxiliary power or energy source for operating an electrical generator or alternator or the like for putting an electrical charge into the batteries of an electric automobile or other vehicle, and is shown and described in such connection, it is to be understood that its utility is not confined thereto.

As is well known, electrically operated vehicles have certain inherent disadvantages. For one thing, the range of operation with a battery charge is considerably limited as the batteries run down rather rapidly and will then require recharging.

Heretofore, as far as we are aware, attempts to provide an auxiliary source of energy for replacing a part of the charge in the batteries as the vehicle is being used utilize some of the energy supplied by the primary power source. Such an arrangement is, of course, not satisfactory since no additional power is supplied that is not derived from said primary power source.

The present invention solves the above problems by providing means for supplying an auxiliary power or energy source that is derived from movements of the vehicle that do not depend on the driving force of the primary power source. In other words, the present invention develops auxiliary power or energy from vehicle movements that do not take power from the primary power source.

The invention may also function as the vehicle suspension system and provide a cushioning or stabilizing effect while acting as an energy generator.

An example of the prior art is disclosed in the Di Perna Patent No. 2,941,613 which discloses an air generator electric vehicle. There is a special generator adapted to apply a charge to the battery when the vehicle is in forward motion. This special generator is operated by ram pressure of air turning a vaned armature. With this arrangement there is air resistance to the auxiliary mechanism which uses some of the energy or power of the primary power source.

SUMMARY OF THE INVENTION

An energy generator embodying the present invention may be attached adjacent each wheel of the vehicle and each of these generators has two main parts, a cylinder, and a piston reciprocally mounted therein, the device being of the double acting type for pumping fluid such as air, for example. The parts are connected between parts of the vehicle that have relative vertical motion. Each end of the cylinder is provided with check valve controlled inlet and outlet the latter being adapted to be connected to a fluid reservoir in which fluid pressure is built up. Pressure fluid from the reservoir is used to drive an electric generator or alternator or the like or other vehicle accessories.

Thus, relative vertical movements of the vehicle parts to which the device is operably connected effects pumping action of the device to pump fluid into the reservoir. This relative vertical movement of the vehicle parts does not take any power from the prime power source of the vehicle and the device will function when the vehicle is operated in reverse as well as forwardly. Thus the invention makes use of hitherto ignored forces resulting from vehicle operation.

A spring is disposed at each end of the cylinder and acts on the piston. With this spring arrangement and a device for each wheel said device may serve as a part or all of the land vehicle's suspension system as well as providing an auxiliary source of energy or power.

The characteristics and advantages of the invention are further sufficiently referred to in connection with the following detailed description of the accompanying drawing which illustrate one embodiment. After considering this example skilled persons will understand that many variations may be made without departing from the principles disclosed and we contemplate the employment of any structures, arrangements or modes of operation that are properly within the scope of the appended claim.

Referring to the drawings which are for illustrative purposes only:

FIG. 1 is a front view of a portion of a vehicle diagrammatically showing a wheel supporting or suspension mechanism with the present invention operably mounted between parts of the suspension mechanism having relative vertical movements;

FIG. 2 is a diagrammatic side elevational view of an energy generator embodying the present invention, a portion being broken away and shown in section to show the interior construction; and

FIG. 3 is a schematic or diagrammatic view of a pneumatic system incorporating the present invention.

Referring more particularly to the drawings, there is shown, FIG. 1, one end of a cross frame member, indicated generally at **10**, of a vehicle, said cross frame member having a central, horizontal part **12**, an upwardly and outwardly inclined part **14** from the upper outward end of which there is a short horizontal part **16**, at least the latter being hollow with front and back walls **18** and **20** and a top wall **22**.

There is a wheel with a tire **24** thereon, said wheel being operably mounted on an axle **26**, the latter having an upwardly extending arm **28** and a downwardly extending arm **30**, said arms **28** and **30** being integral with the axle **26** and fixed relative thereto.

The upper arm **28** has its upper free end pivotally connected to the outer end of a movable arm **32**, said pivotal connection being at **34**. The inner end of arm **32** is pivoted, at **36**, to a support member **38** fixed in the usual well-known manner to the upper wall **22** of the outer horizontal end of the frame member **10**.

Downwardly extending arm **30** of the axle is pivotally connected, at **40**, to the outer end of a movable arm **42**, the other, inner end of arm **42** is pivotally connected, at **44**, to the upwardly and outwardly inclined part **14** of frame part **10**.

A coil suspension spring **46** is operably disposed between the arm **42** and the top wall **22** of the horizontal part **16** of the frame member **10**. One of the energy generating devices, indicated generally at **50**, is operably disposed within the spring **46**.

Referring now to FIG. 2, the device **50** comprises a cylinder **52** closed at its upper end by an upper end wall

and having an upwardly extending axial boss **54** with a tapped recess, not shown, extending from the upper end wall, said recess being closed at its lower or inner end. A connecting rod **56**, having an externally threaded end screwed into said tapped recess, extends upwardly from said boss and is provided with an enlarged bearing element **58** at its upper or outer free end, said bearing element **58** having a transverse bore **60** therein. It is to be understood that when terms or words indicating directions are used, they are to be taken as indicating such directions relative to the views of the drawings.

The lower or opposite end of the cylinder **52** is closed by a lower end wall **62** having an axial bearing **64** for slidable reception of a piston rod **66**, said bearing **64** providing a sealing as well as a sliding support for the piston rod **66**.

Piston rod **66** has a piston **68** attached thereto adjacent the upper or inner end, an end portion **70** of said piston rod extending upwardly from the piston to serve as a bumper to limit telescoping movement of the cylinder and piston. The piston may be attached to the piston rod by any suitable well-known means and said piston has a plurality of exterior annular grooves **72** for reception of piston rings **74**. The piston rings may be of any suitable character but are shown as being O-rings of any suitable material, such as rubber, plastic or the like, there being various types of these rings on the market.

At its outer end the piston rod **66** is provided with an enlarged annular part or bearing element **76** having a transverse bore **78** therethrough.

Each end of the cylinder **52** is provided with an inlet duct and an outlet duct **80** and **82** respectively. The ducts **80** and **82** are connected with the interior of the cylinder by means of passages or ports **84** and **86** respectively. Suitable check valves, including movable check valve members **88** and **90** respectively, control the fluid flow through the inlets and outlets.

Check valve **84** is urged by spring **92** which are controlled by suitable check valves including movable check valve members **84** and **86** respectively. The check valve members are yieldingly urged in the closing direction by springs **88** and **90** respectively. Check valve **84** is urged by spring **88** against a seat at the inner end of a passage **94** through an insert **96** which is secured in the outer end portion of the inlet **80** by any suitable means, the insert being shown as being press fitted in said inlet although it may be threaded and screwed into a tapped end portion of said inlet.

Check valve **90** is urged by spring **98** against a seat at the outer end of the passage **86** leading from the interior of the cylinder adjacent its lower end into the outlet **82**. An insert **100** similar to insert **96** is secured in the outer end of the outlet **82** and has an outlet passage **102** therethrough.

Within the cylinder are springs **110** and **112**, spring **110** being disposed in the lower part of the cylinder and spring **112** being disposed in the upper part of the cylinder. Spring **110** reacts between the wall **62** at the lower end of the cylinder and the piston **68** while spring **112** reacts between the upper end wall of the cylinder and the piston.

The device **50** may be operably mounted between the lever **42** and the upper wall **22** of the transverse frame member part **16**. As shown the bearing element **76** is disposed between the sides of a yoke **114** attached to the lever **42** and is pivotally connected with said sides by means of a pivot pin **116** or the like. The bearing element **58** of the cylinder is similarly connected to the wall **22** of the frame part **16**.

While only one of the devices **50** is shown in FIG. 3 it is to be understood that each wheel may have such a device and each of said devices has its outlet connected to the air reservoir, indicated generally at **120**. Each outlet of the device **50** is connected to a T fitting or fixture **122** by conduits **124** and **126**, there being a conduit **128** connecting the T fitting with the reservoir **120**.

When the vehicle is in forward or rearward motion the wheels move upwardly and downwardly with respective variations in the road and cause the suspension mechanism to be actuated to effect vertical telescoping and extending movements of the cylinders and pistons of the respective devices **50** which results in pumping of air into the reservoir and build up air pressure therein. Air, of course, is drawn into the upper and lower ends of the cylinder as the piston moves downwardly relative to the cylinder and air is drawn into the lower part of the cylinder when the cylinder and piston move telescopically. With opposite movements of the piston relative to the cylinder air is forced or pumped into the reservoir.

The reservoir may be connected with various mechanisms operable by fluid pressure or pressure air. As shown in FIG. 3 the reservoir has an outlet connection **134** with a valve **136** having a conduit **138** connected thereto leading to a device to be operated. The valve also has a connection **140** with a fitting **142** having one arm connected with a valve **144** which in turn is connected by a conduit **146** with a starter **148**.

The fitting **142** also has a connection **150** with a valve **152** which in turn is connected by a conduit **154** with a pressure fluid operated turbine **155** which drives an apparatus **156** for producing or generating current. Such apparatus may be a generator or alternator or the like.

Pressure air may be supplied to the various apparatus by proper operation of the valves **136**, **144** and **152**. Should it be desired to provide a charge to the batteries during operation of the vehicle, the alternator is operated by pressure air from the reservoir which is constantly supplied with pressure air by the devices **50** since there is constantly relative vertical movement between the parts of the suspension system for the vehicle wheels when the vehicle is in motion so that air is constantly being pumped into the reservoir by the devices **50**. Therefore there can be a constant charging of the batteries by this auxiliary energy producing apparatus which will greatly extend the range of the vehicle before the batteries require full recharging.

From the foregoing it will be apparent that the present invention utilizes vertical movement of parts of a vehicle having vertical movement relative to each other and the forces developed by such vertical movements has heretofore not been used or taken advantage of and so not use any power of the prime power source of the vehicle.

Further, with proper spring arrangements of the devices themselves the springs can function to replace in part or entirely the conventional springs and the springs of the devices may also function to cushion or stabilize the suspension action. In other words, the springs of the devices may act as shock absorbers as well as energy producing means and spring suspension means.

Also, the present invention gives feasibility to electric motor powered vehicles by extending the driving range through maintenance of the battery charge for much greater periods of time and operation of the vehicle.

It also may be used to remove some of the battery and engine load of conventional vehicles in the operation of air conditioning compressors, et cetera.

The invention and its attendant advantages will be understood from the foregoing description, and it will be apparent that various changes may be made in the form, construction and arrangement of the parts of the invention without departing from the spirit or scope thereof or sacrificing its material advantages, the arrangement hereinbefore described being merely by way of example, and we do not wish to be restricted to the specific form shown or uses mentioned except as defined in the accompanying claim.

We claim:

1. An energy generator for mounting between actuating parts adapted to have vertical movement relative to each other, comprising:

5

(A) pump means having a pair of cooperating pump parts effecting pumping of fluid upon relative movement of said pump parts;

(B) means for connecting the pump parts to respective actuating parts whereby, upon relative vertical movement of said actuating parts the pump parts are actuated for pumping fluid;

(C) said pump means comprises a double acting pump having a cylinder, each end of said cylinder having a check valve controlled inlet port and a check valve controlled port, said cylinder being imperforate between the ports at the ends thereof;

(D) a piston reciprocally disposed in said cylinder;

(E) a piston rod operably carrying said piston;

(F) said actuating parts for the pump being operably connected to parts of a vehicle having relative vertical movements;

(G) and yielding means in the cylinder acting between the cylinder and piston in opposite directions, said yielding means comprising springs in the upper and

6

lower parts respectively of the cylinder and reacting against the piston in opposed and balancing relationship and serving as part of the suspension system of the vehicle, at least the spring in the lower portion of the cylinder serving to yieldingly support said vehicle.

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GLEN R. SIMMONS, Primary Examiner

U.S. Cl. X.R.

248—358; 267—2, 8; 280—106.5; 290—1; 417—536

United States Patent

[11] **3,527,188**

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[21] Appl. No. **736,692**
[22] Filed **June 13, 1968**
[45] Patented **Sept. 8, 1970**

[54] **POWER-PRODUCING MEANS FOR VESSELS**
4 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **115/4**
[51] **Int. Cl.** **B63h 19/02**
[50] **Field of Search** 115/4; 253/11

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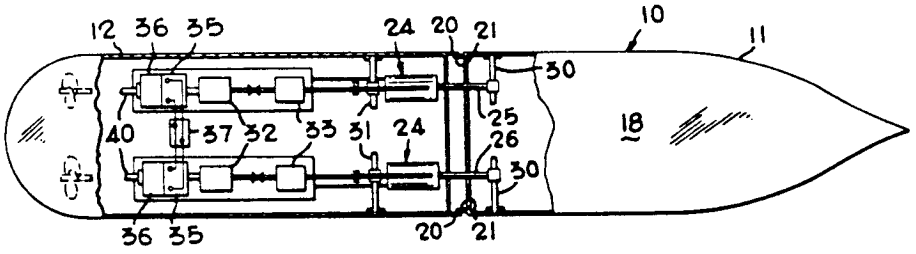
Primary Examiner—Andrew H. Farrell
Attorney—Cohn and Powell

ABSTRACT: The power-producing means includes front and rear hull portions of a vessel coupled together by a transversely disposed hinge member. A pair of plunger and cylinder assemblies are vertically spaced from the hinge, each plunger being attached to one portion of the hull and each cylinder being attached to the other portion of the hull. The plungers are received within the cylinders as the hull portions rotate about the hinge member in response to the undulating motion of the water whereby to translate such energy motion into useful work.



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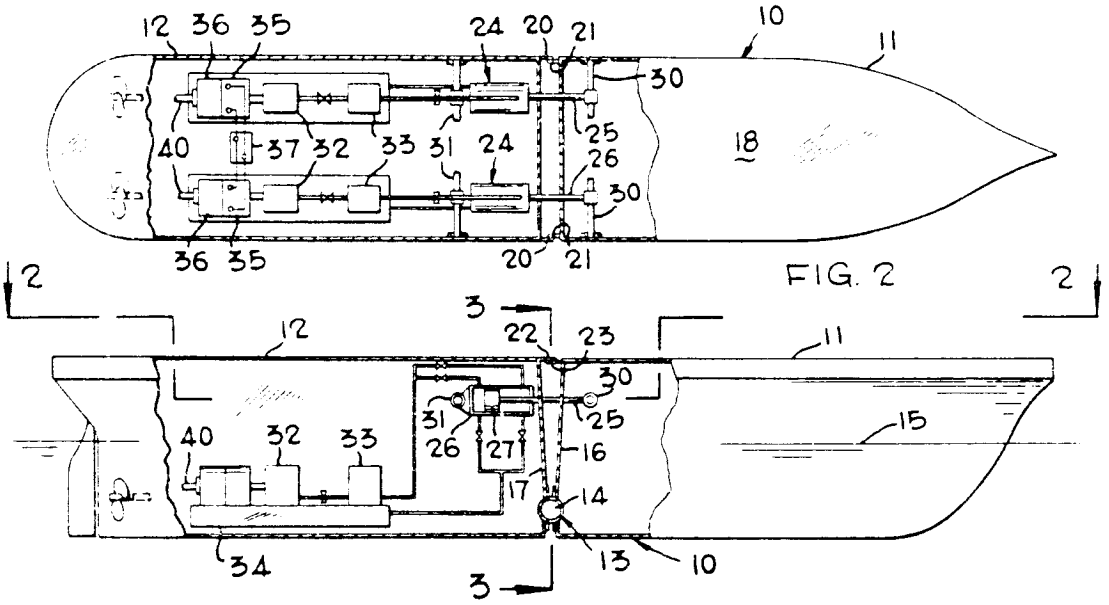

FIG. 1

FIG. 2

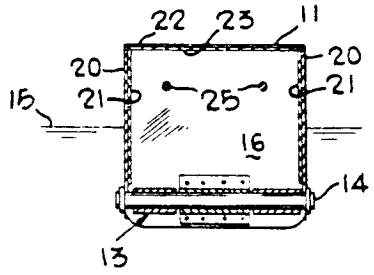

FIG. 3

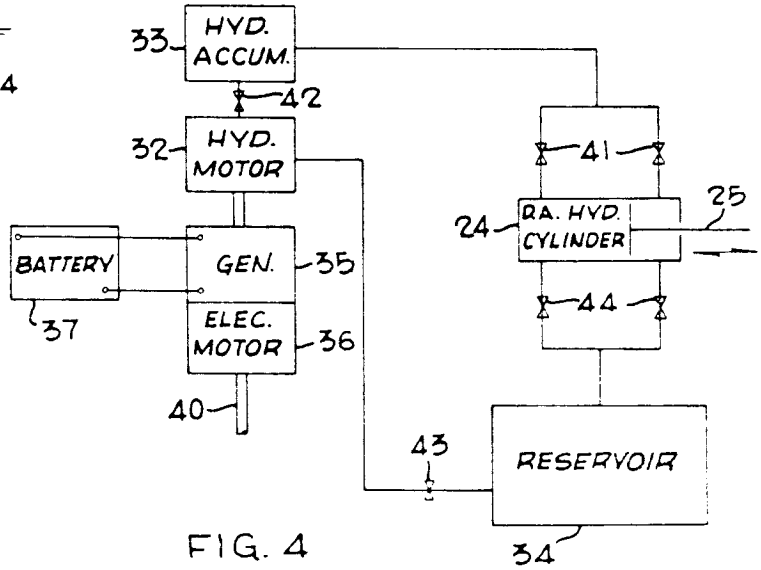

FIG. 4

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Attorneys

1

POWER-PRODUCING MEANS FOR VESSELS

BACKGROUND OF THE INVENTION

This invention refers generally to the production of power from ocean swell and wave motion and, in particular to the conservation of energy resulting from wave action on a floating vessel.

The natural movement of rivers, seas and oceans have long been regarded as a prime source of energy. However, although the available power is practically limitless, the difficulty of tapping it has proved a deterent in the development of this form of power.

Various devices exist which derive power from wave motion, such as occurs with tidal action, ocean swell and the like, but, in general, the devices in the known art are stationery in that they are invariably moored to a buoy or mounted on a permanent structure, such as a pier.

In the usual situation, a buoyant body rises and falls with the wave action and adjusts a balance weight, thereby storing potential energy. Alternatively, the swinging motion of shore waves has been utilized by transmitting this motion directly to large blades swung from a pier or other structure.

Obviously, there are many advantages to be gained from utilizing the undulating motion of natural bodies of water. As a fuel substitute, it is cost free; it presents no pollution problem and the supply is unlimited.

SUMMARY OF THE INVENTION

The power-producing means described herein may be utilized with a moving, water-borne vessel and is not limited to a moored assembly.

Although normal ship construction is modified to the extent necessary to permit hinge and piston operation, the over-all profile is that of a conventional vessel. The cross section will likewise be substantially conventional and permit storage capacity comparable to that offered by any vessel of like tonnage.

The power-producing means includes a pair of bodies including at least one floating body adapted to rise and fall in response to the swell of the ocean, the bodies being coupled together in pivotal relation. An arm is disposed in spaced relation from the coupling means and extends between the bodies, the arm including opposed ends, one end being connected to one body to permit the arm to move in response to the relative movement of the body. Translation means carried by the other body engages the other end of the arm and translates movement of the arm into power.

A powered vessel including front and rear portions provides the body, and the coupling means includes a transverse hinge interconnecting the front and rear portions.

The arm includes a plunger aligned with the length of the vessel, and the translation means includes a hydraulic cylinder cooperating with the plunger, the plunger being pivotally connected to said other body. The longitudinal axis of the plunger is oriented substantially perpendicularly to the axis of rotation of the hinge. A hydraulic circuit receives fluid from the hydraulic cylinder, the circuit including a hydraulic motor, and an electric generator is coupled to the hydraulic motor to produce electric power assisting the operation of the powered vessel.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a side elevational view with the hull partially exposed to reveal the hinge and plunger mechanism;

FIG. **2** is a plan view as taken on staggered line **2—2** of FIG. **1**;

FIG. **3** is a cross sectional view as taken on line **3—3** of FIG. **1**, and

FIG. **4** is a diagrammatic representation of the hydraulic and electrical system.

2

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now by characters of reference to the drawing and first to FIG. **1**, it will be understood the power-producing means is embodied in the hull **10** of a water-borne vessel such as a passenger ship or tanker.

The hull **10** is divided into fore and aft portions **11** and **12** respectively which are coupled together by a transverse hinge member, generally shown by number **13**. The hinge member **13** includes a pin **14** having an axis of rotation disposed below the water line **15**. The fore and aft portions **11** and **12** of the hull **10** constitute a pair of bodies, each of which may rise and fall relative to the other by rotational movement about the axis of the hinge pin **14**.

It will be understood that the fore portion **11** includes an end bulkhead **16** and that the aft portion **12** includes an opposing end bulkhead **17**. The hinge member **13** is mounted on each of the bulkheads **16** and **17** in order to perform its coupling function.

Overlapping side plates **20** and **21** extend inwardly between the fore and aft portions **11** and **12** in order to provide a closure between the two portions of the hull **10**. These sliding plates **20** and **21** extend vertically substantially from the deck **18** to the hinge member **13** and provide the vessel with an outwardly conventional appearance. Deck closure plates **22** and **23** perform a similar function for the deck **18**, and in addition permit traffic to move normally across the gap between the two portions of the hull **10**.

A pair of plunger and cylinder assemblies **24** are disposed in side-by-side relation, substantially symmetrically about the longitudinal axis of the hull **10**. Each assembly **24** includes a plunger **25** extending longitudinally of the hull **10**, and a cylinder **26**, constituting a power translation means, into which the piston head **27** of the plunger **25** is received.

Each plunger **25** is pivotally mounted to the fore portion **11** by a transverse shaft **30**. The shaft **30** is connected to the plunger **25** at the end of plunger **25** remote from the piston head **27** and the shaft **30** is attached to the fore portion **11** of the hull **10**. Similarly, each cylinder **26** is pivotally attached to the aft portion **12** of the hull **10** by a shaft **31**. Obviously, the shafts **30** and **31** may extend across the width of the hull **10** or may be secured to interior longitudinal bulkheads **16** and **17**.

The plunger and cylinder assemblies **24** are preferably of the double-acting variety. In operation, motion is induced into the assemblies **24** by rotation of hull portions **11** and **12** about the hinge pin **14**. Each assembly **24** supplies fluid to an associated hydraulic motor **32** by way of hydraulic accumulators **33**. From the hydraulic motor **32**, the fluid passes to a reservoir **34** and thence is returned to the cylinders **26**.

The hydraulic motor **32** is utilized to drive an electric generator **35** which is, in turn, utilized to power an electric motor **36**. The generator also feeds a storage battery **37**. The output drive shaft **40** of the electric motor **36** may be used to provide a prime mover for the various auxiliary systems in the ship, and the generator - battery combination may, in addition to supplying the electric motor **36**, supply electricity for lighting and the like. Power from the motor **36** may also be utilized to assist in propulsion of the vessel. The hydraulic and electrical systems may be mounted on the reservoir **34** for convenience of arrangement.

FIG. **4** is a diagrammatic representation of the power-producing system and, of course, the various control valves **41**, **42**, **43** and **44** perform the usual cut-off function of such valves and do not require specific description, their use being obvious.

It is thought that the functional advantages of this power-producing means have become fully apparent from the foregoing description of parts, but for convenience of disclosure, the operation of the structure will be briefly described.

There is no time when the ocean is completely still and in general the motion of the water is considerable. In the preferred embodiment wave action and ocean swell may operate effectively against both the fore portion **11** and the aft

portion **12** of the hull **10**, and the varied nature of ocean swell over an extended distance, makes it inevitable that a differential force will exist, tending to rotate the portions **11** and **12** about the hinge pin **14** relative to each other.

As one portion of the vessel moves relative to the other, it is clear that, because of their rotation about the hinge pin **14**, the pivot points represented by shafts **30** and **31** likewise move relative to each other. Because of the plunger and cylinder assembly **24** connected between the shafts **31** and **30**, the plunger is retracted into the cylinder as the gap between the hull **10** closes. When this happens, hydraulic fluid is forced into the hydraulic circuit and drives the hydraulic motor **32**. The hydraulic accumulator **33** functions in the accustomed manner to insure that the drive is smooth.

A typical vessel size will be considered to appreciate what quantitative forces are involved. The figures referred to below are intended only to be approximate and exemplary and are not to be considered in any way limiting.

As an example of the forces involved, consider a vessel having a length of 300 feet. Such a vessel will typically have a length to beam ratio of about 1 to 10 which will provide a width of 30 feet. It will be supposed that the draft is say 15 feet. It will be further supposed that the wetted area of such a vessel would be 15,000 square feet.

The power required to drive such a ship is a function of the ship resistance, the velocity of the vessel and the efficiency. The ship resistance is a factor measured in pounds per square foot of wetted area and is equal to the sum of the frictional resistance and the wave resistance. For a vessel of the stated dimensions, the ship resistance will be assumed to be six pounds per square foot of wetted area. Further the velocity will be assumed as 20 knots (33.8 f.p.s.) and the efficiency of the drive 60 percent. The horse power required to propel such a ship is:

$$\text{H.P.} = \frac{R \times V}{550} \times \frac{1}{E}$$

$$= \frac{(6 \times 15{,}000) \times 33.8}{550} \times \frac{100}{60}$$

$$= 9{,}000 \text{ approx.}$$

A typical displacement of such a ship would be 5,000 tons. Thus one of the two portions which make up the vessel herein discussed might be assumed as weighing 2,500 tons or 5,000,000 pounds. It will be readily understood that the upward movement of 5,000,000 pounds at the rate of say one foot per second results in a substantial quantity of work done per second, sufficient even to contribute to the propulsion of the vessel.

It is hoped that the above figures give some indication of the enormous forces available as the hull portions **11** and **12** rise and fall, in comparison with the drive power required. By taking advantage of such forces, the natural movement of the sea is utilized in a power medium in much the same way as the wind was utilized in a power medium for sailing ships.

We claim:

1. In an ocean-swell actuated, power-producing means

a. a power vessel including front and rear floating portions having face to face adjacent ends, said portions providing a pair of bodies adapted to rise and fall in response to the swell of the ocean,

b. coupling means attaching the bodies together in pivotal relation including a transverse hinge interconnecting the front and rear portions;

c. an arm disposed in spaced relation from the coupling means, the arm including opposed ends, one of said ends being connected to one body, the arm moving in response to the relative movement of the bodies;

d. translation means carried by the other body, the translation means engaging the other end of the arm and translating movement of the arm into power, the translation means and the arm extending between said face to face adjacent ends of the bodies,

e. the arm including a plunger, substantially longitudinally aligned with the power vessel and having said one end pivotally connected to said one body; and

f. the translation means including a hydraulic cylinder cooperating with the plunger, the cylinder being pivotally connected to said other body.

2. A power-producing means as defined in claim **1**, in which:

g. a hydraulic circuit receives fluid from the hydraulic cylinder;

h. the hydraulic circuit includes a hydraulic motor; and

i. an electric generator is coupled to the hydraulic motor whereby to produce electric power, assisting propulsion of the powered vessel.

3. In an ocean-swell actuated, power-producing means

a. an elongate powered vessel including front and rear floating portions having face to face adjacent ends;

b. hinge means interconnecting the floating portions, the said portions rotating relative to each other in response to the swell of the ocean about a substantially horizontal hinge axis of rotation;

c. at least two hydraulic plunger and cylinder assemblies disposed in side-by-side relation and extending between the face to face adjacent ends of the front and rear floating portions in spaced vertical relation to the axis of rotation of said hinge means;

d. at least one transverse shaft mounted to the front portion;

e. at least one transverse shaft mounted to the rear portion; and

f. each hydraulic plunger and cylinder assembly including an associated plunger and cylinder, the plunger being pivotally attached to an associated transverse shaft mounted to one of said floating portions in radial relation to the hinge and the cylinder being pivotally attached to an associated transverse shaft mounted to the other of said floating portions in radial relation to the axis of the hinge, the plunger including a piston head received into the cylinder as the front and r rear portions rotate relative to each other about the hinge means.

4. A power-producing means as defined in claim **3**, in which:

g. each hydraulic plunger and cylinder assembly extending substantially longitudinally of the elongate vessel between said transverse shafts.

Springfield Men Invent Vehicle That Runs Only On Air

By TED BLACKMAN

SPRINGFIELD (UPI) — For years the dream of science fiction writers has been the vehicle that would run on some cheap, universally available fuel.

Something like air, for example.

A ridiculous notion, of course except for two Springfield men, who have actually built and driven a van which uses nothing but air as its primary fuel.

Ridiculous? Impossible? That's the reaction John Lunsford and Steve Hudspeth have faced. But they've managed to prove their case for the air-driven engine well enough to get two patents on the air-fuel processes they invented to drive a standard van.

"The patent attorney called it an 'air pulsing system,'" Lunsford of 1061 B St., said.

Hudspeth, described the basic process as a "compressed air amplifier."

The Engine

Inside the van, a complex-looking maze of tubes and pipes connect three cylinders to a 50-horsepower Cyclone engine. The engine has five cylinders and is called a "radial."

It's the old-fashioned radial engine, the sort World War I biplanes sported with the cylinders arranged around the crankshaft.

A difference: The engine is hydraulic. Its pistons are forced back and forth by air pressure instead of an exploding mixture of air and gas.

This is where the compressed air and the three "amplifiers" come in.

It's also where an ingenious system the two designed to take advantage of the condition of many Springfield streets comes into play.

First, compressed air from an ordinary tank just like those available at welding supply shops passed through electrically timed valves into the amplifiers.

Forces Pistons

The air rushes into the top of the amplifier cylinders, forcing pistons down. As this happens, air in the bottom of the cylinders is also compressed, thus adding to the volume of compressed air available to power the motor.

Still more compressed air is provided from the motor itself: As air passes through the radial cylinders, it is exhausted back to the amplifiers. In effect, the engine recycles its own exhaust which is only the same fresh air that powered it in the first place.

Even Springfield's rough streets can help power the vehicle. Lunsford and Hudspeth designed a hydraulic pump system to replace the van's shock absorbers. As the car bumps over rough spots in the road, its lunging weight compresses still more air.

That air is fed into the amplifying system and on to the motor.

Besides compressed air, the system needs only a standard car and ordinary V-8 engine, Lunsford asserted.

Speed Lacking

isting system. "Weve got it geared down so much, it'll only go 12-15 miles an hour," Lunsford said, "We didn't want to take a chance on losing power."

The men haven't done any mileage tests yet, either. "We have some air leaks in our system, so the tests really would not prove much," Lunsford noted.

They point out that their system could easily be more efficient than proposed electric cars with their tons of batteries required for even short trips. "And it's much easier to switch tanks of air than to recharge all those batteries," Hudspeth chuckled.

Now that both the air amplifiers and the hydraulic shock system have received patents, the two are working on ways either to get money to develop the compressed-air drive scheme themselves or, if forced to, to let someone else do the engineering and development so it can be mass produced.

"I even took night classes at the university so I could learn something about how to sell it," said Hudspeth, who is an electrician for Rosboro Lumber Co.

Lunsford is a millwright for Cone Lumber Co., in Goshen. ABOVE for Weekend Editons

DRAWS POWER FROM AIR — Steve Hudspeth, left, and John Lunsford, of Springfield, are proud of their hydraulic bicycle that runs on air. The two men have invented an engine that science fiction writers have written about for years — one that runs on a cheap, available fuel. Hudspeth and Lunsford have patented their "air pulsing system" and actually power a van with it. (UPI)

United States Patent

Hudspeth et al.

[15] 3,688,859

[45] Sept. 5, 1972

[54] VEHICULAR AIR COMPRESSION SYSTEM

[72] Inventors: Steve A. Hudspeth; John B. Lunsford, both of Springfield, Oreg.

[73] Assignee: FMA, Inc., Eugene, Oreg.

[22] Filed: Oct. 8, 1970

[21] Appl. No.: 79,125

[52] U.S. Cl. .....180/66 B, 280/124 R, 417/233

[51] Int. Cl. B60k 25/10

[58] Field of Search.....280/124 R; 180/54 R, 66 B; 417/231, 233

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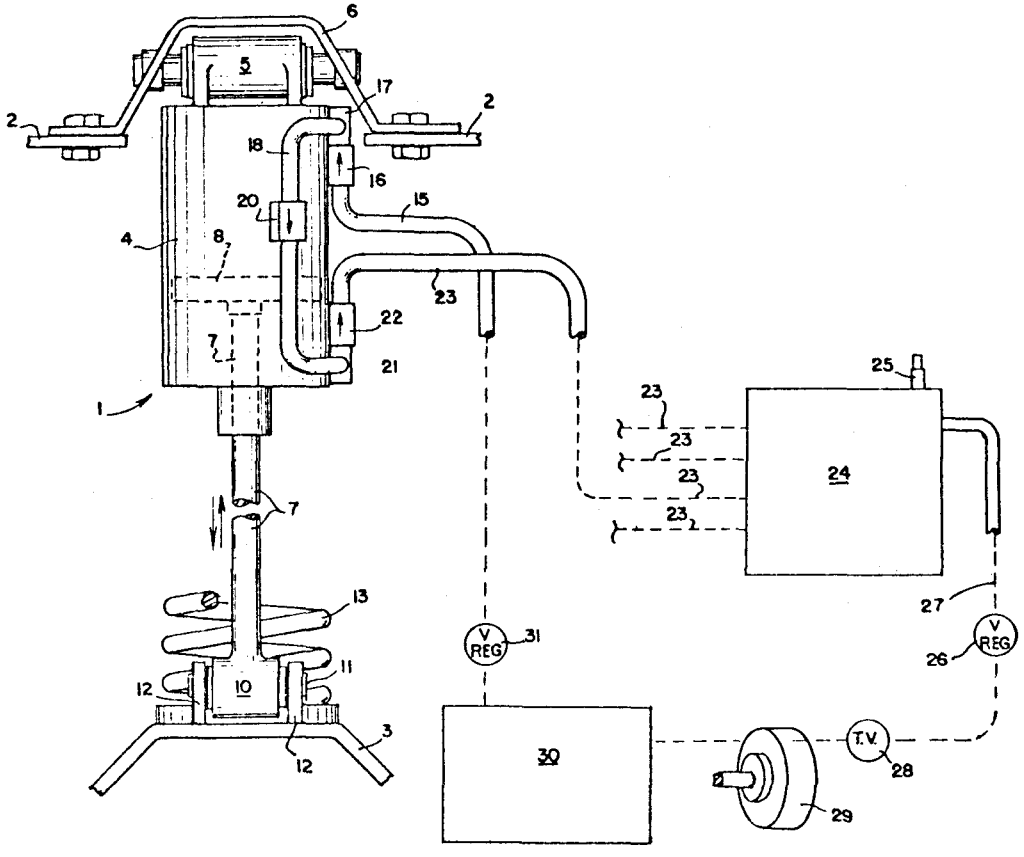
Primary Examiner—Philip Goodman

Attorney—James D. Givnan, Jr.

[57] ABSTRACT

A cylinder having a piston and piston rod assembly reciprocated by a wheel suspension member of the vehicle for the transfer of a fluid to a pressure storage tank. A fluid motor downstream from the tank is operated by a valve regulated flow of air for the controlled operation of various powered systems of the vehicle. An air flow circuit is completed back to the cylinder via a second tank constituting a source of low pressure air. The cylinder is simultaneously charged with a quantity of air on one side of the piston while air is exhausted, under pressure, on the opposite side of the piston.

3 Claims, 2 Drawing Figures



PATENTED SEP 5 1972 3,688,859

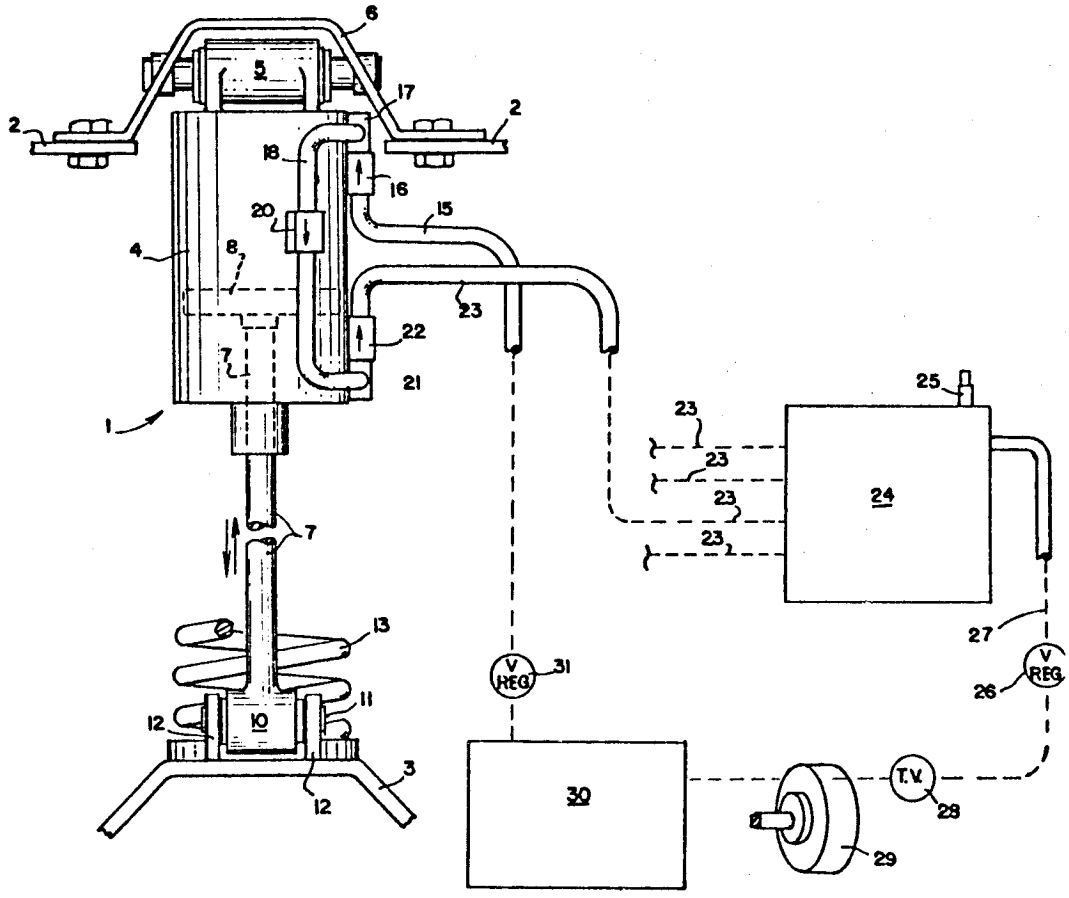


Fig. 1

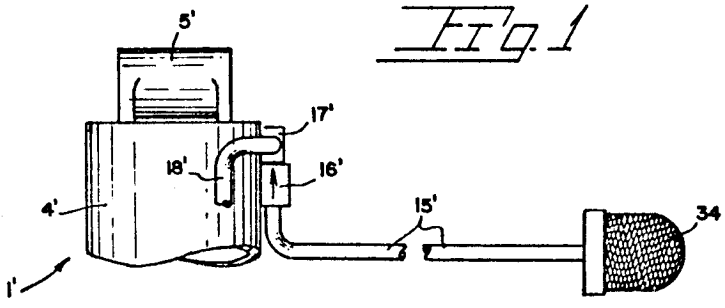


Fig. 2

STEVE A. HUDSPETH
JOHN B. LUNSFORD
INVENTOR.

BY
AGENT

VEHICULAR AIR COMPRESSION SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to a vehicular carried air compression system and more particularly to such a system utilizing vertical travel of the vehicles wheel suspension members as a source of power for air pressurization.

In the present field of invention automotive components operated by differential air pressure are, for the most part, of the vacuum type. They are dependent on a continuous source of vacuum or negative pressure for their operation, such a source commonly being the intake manifold of an internal combustion engine. In distinction, the present invention provides for a continuous flow of pressurized air through an air motor the power of which may be utilized for various automotive purposes including powering the vehicle.

SUMMARY OF THE INVENTION

The present invention is embodied within an air compression system for installation on a vehicle wherein vertical wheel motion is utilized as a source of power. A piston responsive to wheel motion works within a cylinder carried by the vehicle frame or chassis. A wheel suspension member of the automobile in its movement toward and away from the frame while the vehicle is underway actuates the piston in a continuous manner to forcefully exhaust air from the cylinder to a pressure storage tank. The downstroke of the piston exhausting the air under pressure is in compliance with normal wheel suspension movement wherein the automobile suspension member is moved downwardly by means of a spring or like component of the automobile.

An important object of the present invention is the provision of an air cylinder having a piston in continuous motion in response to vertical motion of the automobiles suspension member during travel.

The air cylinder utilizes a sequential flow of air passing through a series of check valves which permits the cylinder to operate in the nature of an air pump. Normal travel of the vehicles suspension member and hence the "ride" of the vehicle is largely unaffected during upward movement of said member. Oppositely, downward movement of the suspension member to its normal position, as urged by a vehicle spring member, results in the air being exhausted from the lower end of the cylinder, which advantageously accomplishes dampening of wheel motion similar to that affected by a shock absorber unit.

BRIEF DESCRIPTION OF THE DRAWING

In the accompanying drawing,

FIG. 1 is a side elevational view of a wheel air cylinder shown with associated vehicle components and with the remaining system components being shown in schematic form, and

FIG. 2 is a schematic showing a modification of the present system.

DESCRIPTION OF PREFERRED EMBODIMENTS

With continuing reference to the drawing wherein applied reference numerals indicate parts similarly identified in the following specification, the reference numeral 1 indicates generally an air cylinder of the present invention disposed intermediate a vehicle frame member 2 and a wheel suspension member of the vehicle respectively. Both the frame member and the wheel suspension member are shown in fragmentary form and may be considered typical of conventional vehicle construction.

The air cylinder comprises a cylinder 4 adapted at its upper end by means of a boss at 5 for reception of a pin 9, the latter in bracketed attachment at 6 to the vehicle frame 2. The pin 9 extends through boss 5 for reception within the bracket 6. Indicated at 7 is a piston rod integral with a piston 8 for permitting travel substantially the length of cylinder 4. The lower terminus of piston rod 7 is also provided with a boss 10 within which a pin 11 is received for retention by a pair of plates 12 on the wheel suspension member 3. The bracketed attachment so provided for the upper and lower ends of the air cylinder 1 permits lateral displacement of same during closing movement between suspension member 3 and the vehicle frame 2.

The wheel suspension member 3 carries the lower end of a vehicle suspension spring 13 which terminates oppositely at its upper end in supporting engagement with the vehicle frame 2 in a conventional manner. The placement of an air cylinder 1 intermediate the frame 2 and wheel suspension component 3 of a vehicle is not restricted to the manner shown and described, the present frame and suspension member disclosure is intended only as being typical of an air cylinder installation. It will be recognized that additional such air cylinders located adjacent the remaining wheels of the vehicle may be associated with other types of suspension components, e.g., leaf springs or torsion bars and requiring but workmanlike modifications of the present invention.

For operation of the air cylinder 1 a requirement exists that under normal spacing of the vehicles frame 2 and suspension component 3 the cylinders piston rod 7 will be in an extended position to locate the piston 8 in spaced relationship from the upper end of cylinder 4. Obviously a sufficient travel for piston 8 must be provided so as to permit normal flexing of spring member 13 during vertical wheel travel while the vehicle is underway.

A cylinder inlet line or supply conduit at 15 provides a source of air to the upper end of the air cylinder via a ball check valve 16. A cylinder fitting 17 receives the incoming flow of air past the check 16 (in the direction indicated) and directs same into the interior of the cylinder upon downward movement of piston 8. An air transfer conduit 18 is in communication at its upper and lower ends with like ends of cylinder 4 permitting transfer of air therebetween. A second ball check valve at 20 restricts passage of air to the downward flow indicated for entry of the air into the lower end of the cylinder via a second cylinder fitting 21. An exhaust conduit line at 23 is also in communication with cylinder 4 via a check valve 22 and the fitting 21 to direct air exhausted from the rod side of piston 8 to a pressure storage tank at 24. Additional outflow lines from other (not shown) air cylinders are indicated at 23. Such other air cylinders are similarly associated with each of the other three wheel suspension members.

Tank 24 for the storage of air pressurized by the air cylinders is fitted with a valve 25 for charging of the tank from an external source of pressurized air as for instance an automobile service station facility. If desired, tank 24 may be in the nature of an accumulator incorporating a movable diaphragm which is biased by mechanical or fluid means against the stored charge of pressurized air.

A relief valve 26 downstream from the tank in a conduit 27 limits the air pressure valve within the tank while a throttle valve 28 provides for control of the air flow through the conduit 27 and hence the volume of air delivered to an air driven motor at 29 for conversion of the air flow to useful mechanical force. Motor 29 may be one of several types commercially available, such as for example a sliding vane type motor.

In one form of the invention a low pressure tank 30 is charged by the exhaust flow from motor 28 at approximately 10 PSI (above atmospheric). A pressure regulator is indicated at 31. The tank 30 provides a source of air, under pressure, to the inlet line 15 to complete an air system circuit to the air cylinder 1.

For purposes of converting the constant pressure flow from storage vessel 24 into a pulsating air flow in conduit 27, if such is desired, the addition of the structure described and claimed in a copending patent application, filed by the present inventors and entitled Air Pulsing System may be made.

In operation upon retraction of piston rod 7 as occurs upon the moving vehicle wheel encountering a bump the air above piston 8 is restricted by check valve 16 to transfer via conduit 18 to the rod side of piston 8. With the cylinder area below the piston 8 enlarging as the piston rises, the air moving through conduit 18 will be drawn into said area in view of tank pressure in exhaust line 23. At the limit of upward piston movement the suspension spring 13 will be compressed with subsequent extension of the vehicles spring 13 occurring to return the vehicle frame 2 and the vehicle suspension component 3 to their normal spaced relationship to simultaneously extend piston rod 7 moving piston 8 downwardly to expel air from the rod side thereof. The foregoing cycle of operation applies regardless of the magnitude of travel of the frame 2 and wheel suspension component 3. Air is accordingly displaced by each of the constantly moving air cylinders on a vehicle for transfer to tank 24. As the wheels of the vehicle are in constant vertical movement with respect to the vehicle frame an adequate volume of air is pumped to the tank 23.

The riding qualities of the vehicle may be retained by varying suspension components such as spring 13 with the present unit functioning to dampen spring movements.

As shown in FIG. 2 a modified embodiment of the present invention dispenses with the low pressure tank 30 and regulator 31 permitting the air motor 29 to exhaust to the atmosphere. An inlet line at 15' draws atmospheric air through an air filter unit at 34. The remaining components in the modified form of the invention are the same as earlier described and are identified with like prime reference numerals.

While the invention has been described in connection with a gaseous media such as air it will be apparent that utilization of a liquid media is also feasible.

While we have shown but two embodiments of the invention it will be apparent to those skilled in the art that the invention may be embodied still otherwise without departing from the spirit and scope of the invention

Having thus described the invention what we desire to secure under a Letters Patent is:

1. An air compression system for a vehicle deriving a compressive force from relative movement between the spring supported vehicle frame and a wheel suspension member of the vehicle, said system including,

at least one air cylinder having a piston and piston rod, said cylinder and piston rod oppositely attached to the vehicle frame and the wheel suspension member whereby piston and cylinder travel will occur during relative frame and suspension member movement,

a transfer conduit communicating the opposite ends of said cylinder,

a supply conduit in communication with one end of the cylinder,

an air pressure storage vessel,

exhaust conduit means extending from the other end of said cylinder to said storage vessel,

check valves associated with said supply, transfer and exhaust conduits to permit air flow from one end of the cylinder into the opposite end of the cylinder upon reciprocal piston movement during relative movement between said vehicle frame and the wheel suspension member to permit said air cylinder and piston to function in the manner of a pump to charge said storage vessel,

an air motor operated by a flow of pressurized air from said storage vessel for powering one or more vehicle systems, and

a second pressure storage vessel to receive the exhaust flow from said air motor, said supply conduit terminating at one of its ends in communication with the last mentioned vessel to provide a flow of pressurized air to said cylinder.

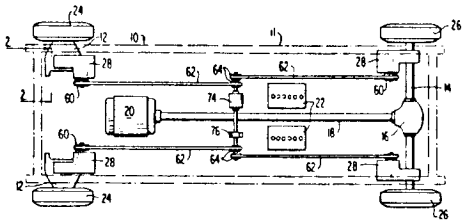
2. The air compression system as claimed in claim 1 wherein the first mentioned pressure storage vessel is of the accumulator type.

3. The air compression system as claimed in claim 1 wherein the first mentioned pressure storage vessel is adapted with valve means to permit periodic charging of the vessel with pressurized air from an external source.

* * * * *

JANUARY 21, 1975

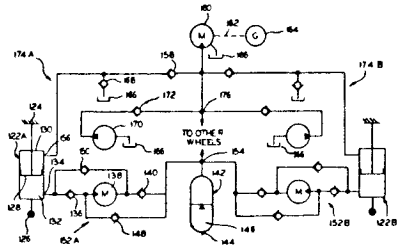
3,861,487
ELECTRIC POWER MEANS FOR VEHICLES
Walter L. Gill, 225 S. Buena Vista, Redlands, Calif. 92373
Continuation-in-part of Ser. No. 360,959, May 16, 1973. This application June 27, 1973, Ser. No. 374,127
Int. Cl. B60k *25/10*; B60l *11/00*
U.S. Cl. 180—65 R 10 Claims



1. A vehicle provided with means for supporting said vehicle for movement over a supporting medium and adapted to carry an electric system and a battery for powering such system, said vehicle comprising two relatively reciprocatory parts, means supporting one said part from the other said part for enabling relative movement therebetween along at least two different non-colinear paths, means connected between such parts for converting such relative movement into rotary mechanical power, power reserve means receiving and storing said rotary mechanical power, and current generating means for recharging said battery and driven by said power reserve means.

NOVEMBER 25, 1975

3,921,746
AUXILIARY POWER SYSTEM FOR AUTOMOTIVE VEHICLE
Alexander J. Lewus, 9844 N. 11th Ave., Phoenix, Ariz. 85021
Continuation-in-part of Ser. No. 313,242, Dec. 28, 1972, abandoned. This application Mar. 21, 1974, Ser. No. 453,293
Int. Cl.[2] B60K *25/10*
U.S. Cl. 180—53 R 10 Claims



1. An auxiliary power and suspension system for an automotive vehicle or the like, comprising a vehicle frame, a body mounted on the frame, auxiliary equipment for the vehicle and a plurality of supporting wheels for the vehicle, said auxiliary power and suspension system comprising:

suspension means for mounting the wheels on the vehicle frame, said suspension means allowing limited vertical movement of the wheels relative to the frame in response to irregularities and changes in contour of terrain traversed by the wheels;

power transmission means, connected to at least two wheels and to the vehicle frame, for actuation in response to relative vertical movement therebetween;

and power conversion means, connected and actuated by said power transmission means, for converting mechanical kinetic energy applied to said power conversion means through said power transmission means into another energy form more readily useable in operation of said auxiliary equipment;

said power conversion means comprising hydraulic pump means comprising a plurality of double-acting cylinders, a reciprocal piston dividing each into two chambers, and inlet-outlet ports in said chambers;

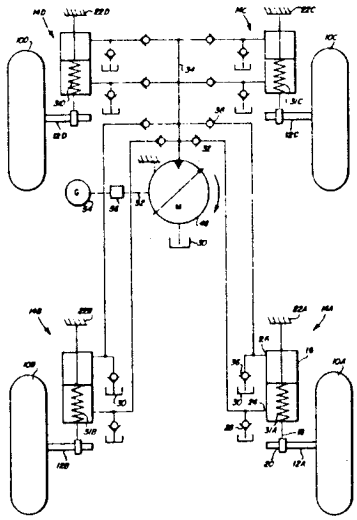
a transmission line communicating with said chambers through said inlet-outlet ports, valve means in the transmission line to regulate the flow of hydraulic fluid;

and hydraulic motor means communicating directly through said transmission line and valve means with said chambers and actuated by the hydraulic pressure therein; said motor means, transmission line, valve means and at least one chamber of each double-acting cylinder comprising a generally fluid tight hydraulic circuit substantially completely filled with fluid and operable independent of any system reservoir; and

said auxiliary power and suspension system supporting the entire weight of the vehicle which acts on said wheels.

OCTOBER 20, 1981

4,295,538
AUXILIARY POWER SYSTEM FOR AUTOMOTIVE VEHICLE
Alexander J. Lewus, 9844 N. 11th Ave., Phoenix, Ariz. 85021
Continuation of Ser. No. 926,373, Jul. 20, 1978, abandoned, which is a continuation of Ser. No. 812,528, Jul. 5, 1977, abandoned, which is a continuation of Ser. No. 633,825, Nov. 20, 1975, abandoned, which is a continuation-in-part of Ser. No. 453,293, Mar. 21, 1974, Pat. No. 3,921,746. This application Sep. 17, 1979, Ser. No. 76,081
The portion of the term of this patent subsequent to Nov. 25, 1992, has been disclaimed.
Int. Cl.[3] B60K *25/10*
U.S. Cl. 180—165 5 Claims



1. A suspension and auxiliary power system for a vehicle having a frame, a power consuming load on said frame, and at least one supporting wheel adapted to move vertically relative to said frame, said system comprising: a fluid pump including a housing adapted to be connected to one of said frame and said wheel and a reciprocal piston adapted to be connected to the other of said frame and said wheel, said housing and piston forming at least one fluid pumping chamber whose volume is expanded and contracted by vertical movement between said frame and said wheel; a uni-directional fluid motor; said motor adapted to drive said power consuming load; and fluid circuit means connecting said chamber to said motor said circuit means including a first check valve for directing fluid only from said chamber directly to said motor and a second check valve for directing fluid only from a source of fluid to said chamber, whereby said pump acts as a fluid suspension system, supporting at least a part of the weight of said vehicle on said one wheel, and whereby the loading on said motor of said power consuming load causes said motor to act as a shock absorber to said pump.

Fort Wayne Journal-Gazette Sat., Aug. 18, 1979

See U.S. Patent #3847058

Backyard inventor's brainstorm may have us driving on air

By SHERMAN GOLDENBERG
Staff Writer

SALAMONIA — Robert T. Manor has ...nted something so logical, so obvi... it's almost embarassing.

...ieve it or not, this Jay County mon... dealer and backyard inventor has ... he last eleven years perfecting ... tenting an automobile that runs on ...hat's right. On air. It's just as sim... — or as complicated — as that.

The reason I started on it was pollu...," Manor said Friday, standing in his ...rage. "The energy crisis wasn't even ...rd of when I started. At that time, ... late 1960s, I went up to Syracuse, ... Y., to see my sister. And though the ...ople there didn't seem to notice the ...ution, I certainly did. My eyes water... My nose burned. I thought it was ...ful."

So Manor, who never graduated from ...h school, went to work on an idea he ...d nurtured since the 1940s when he ...ked with air compressors on a sand... ...sting job: Use a small electric motor ...fill compressed air tanks. Patent an ...ine with pistons that will respond to a ...ect blast of air, much like a steam en...e's. Then devise a collector system to ...ture the spent air and return it to the ...rage tanks to complete the cycle.

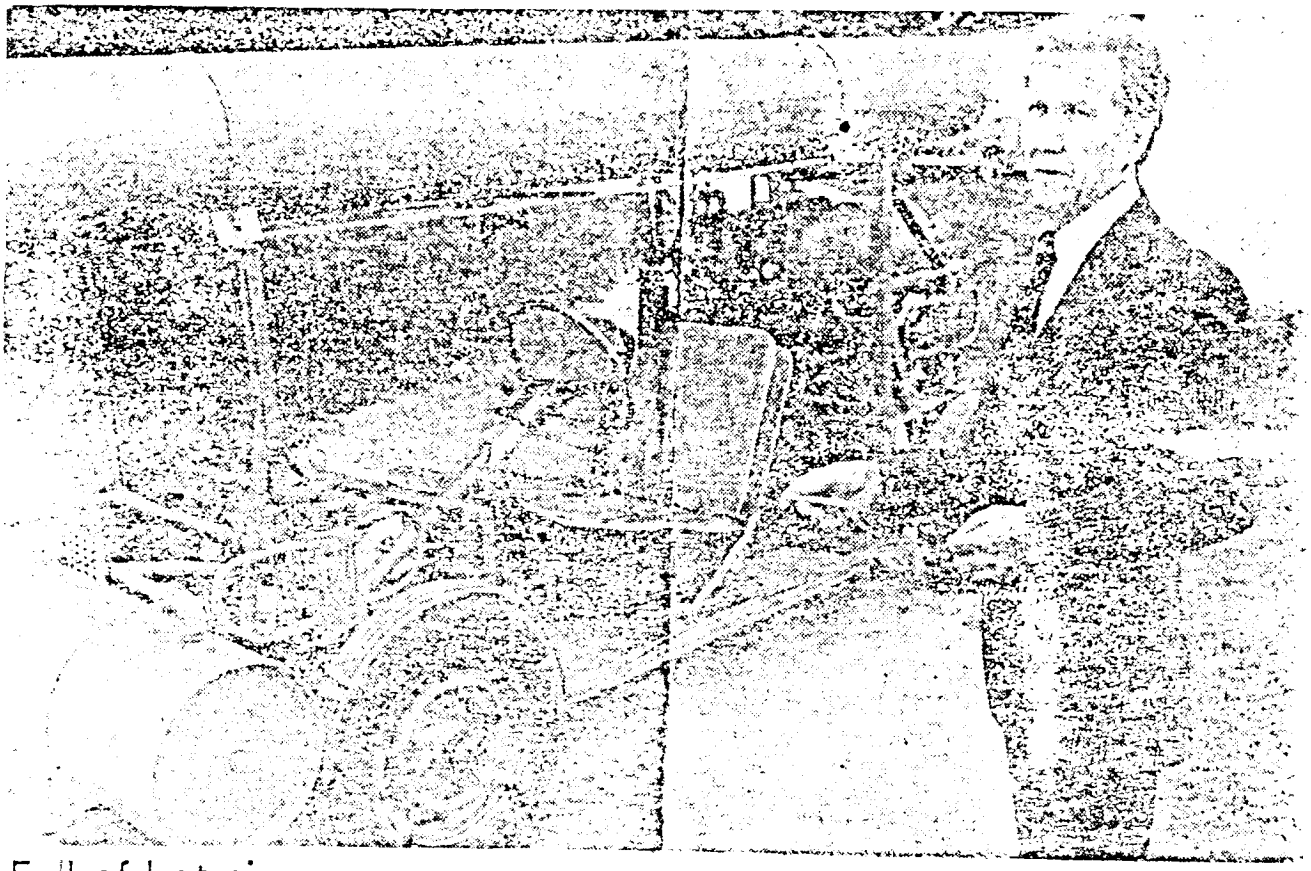
...and — voila — you have the potential ... power cheaply and cleanly whole ...ts of buses and millions of gas-guz... automobiles.

"If he had had all the money in the ...rld, Manor said, he would have car...d a scale model and performed more ...periments beforehand. His prototype ...uld have look more polished, and probably would have incorporated a tubular steel frame instead of an old Volkswagen body. But, he says, the funds were limited. His version cost about $30,000, not counting years of labor.

Therefore, this 54-year-old inventor sounds almost apologetic when he shows you his amazing car, a genuine contraption that looks and sounds like an inspiration of cartoonist Rube Goldberg. "This is just the basic idea," said Manor, pointing out flaws. "I didn't design it for speed or endurance. I just designed it to power a car. That was all of it."

But while the car may be crude by General Motors standards, said Manor, it is undoubtedly the only machine like it in existence.

Two 105-gallon air tanks are mounted on the roof and filled to a pressure of about 120 pounds, close to that of a truck tire. Pressure is infused with an electric motor powered by current from a wall socket. By pushing a lever between the front seats, the driver sends air into the converted four-cycle, gasoline engine and sets the auto in motion. As it moves along with a rhythm, the used air is



Full of hot air

Robert T. Manor, a Jay County monumen... dealer and backyard inventor, has spent the last 11 years tinkering away at an air-fueled automobile. His brainchild has come to a pat... ented fruition, and Manor is looking for pote... tial backers. — Staff photo by Sherma... Goldenberg

piped in to three smaller exhaust tanks welded to the front and back.

Manor has a total of 17 patents on his engine and unique compressors. These double-action, spring-like compressors, stationed where the shock absorbers would normally be, are designed to return a small amount of compressed air to the storage tanks every time the wheels bounce across the pavement. About 10 per cent of the total air volume is lost to friction in each cycle. And, eventually, the storage tanks must be re-energized with the electric motor.

But this is just the prototype, warns Manor, adding that the next model will utilize a combustion engine that automatically re-energizes the storage tanks when the pressure drops. He expects the new air-powered vehicle, an old Ford van, to go 60 miles per hour with the range improved from two to 1,000 miles. The repumping process, he maintains, will require about a gallon of gas for every 85 miles on the road.

Manor says he would eventually like to see his idea perfected by engineer with a solid financial backing. He has contacted several major corporations, along with President Carter, without any positive response as yet. Manor, however, said he won't put his family's livelihood on the line trying to sell his ideas. He said he's heard of too many inventors who made "fools of themselves" that way.

Having come this far without a federal grant, Manor's prepared to go it alone or with a small team of private investors. After all, he explained, money was never his main objective.

"Money is not my main interest in it," he said. "It seems to me we've done a pretty bad job in the last 20 years as far as making a future for our children and grandchildren. And with atomic energy ... we may end up with no future generation at all. So, I thought, why not make a vehicle that doesn't pollute? You're certainly not going to destroy the world with it."

3,980,152

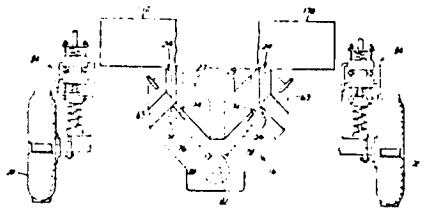
AIR POWERED VEHICLE

Robert T. Manor, P.O. Box 95, Salmonia, Ind. 47381

Division of Ser. No. 341,348, March 14, 1973. This applicatio
Apr. 5, 1974, Ser. No. 458,178

Int. Cl.² F16F 11/10

U.S. Cl. 180-66 B 8 Clai



1. For use on a vehicle, a suspension type compressor comprising a cylinder device having a reciprocable piston which defines two pressure chambers therewith, a piston rod secured to said piston and extending axially therefrom, means for securing said cylinder device and piston between the frame and axle of a wheeled vehicle; said cylinder device including two separate heads arranged one above the other, means mounting said heads for limited relative movement, means yieldably urging said heads toward each other, and intake and exhaust valve means in each head responsive to reciprocation of said piston in said cylinder device for drawing gaseous fluid into and forcing such fluid out of said chambers.

Although I support the spirit of air car inventors everywhere, and the idea of air-pumping shock absorbers is thermodynamically sound, the idea of putting bumps on tires to make sure the shock absorbers are always pumping air is incorrect because it would take more energy to go over the little bumps than could be produced by the pumps in the form of compressed air. The bumps must be outside the car--on the road--to keep from violating the laws of physics.

Manor's 1999 patent # 5957234 is for a closed-cycle air car engine that doesn't use shock absorber compressors or bumps on the tires.

54 Page 1 of a 13-page patent

United States Patent [19]

Manor

[11] **3,847,058**

[45] **Nov. 12, 1974**

[54] **VALVE MECHANISM FOR AN AIR OPERATED RECIPROCATING ENGINE**

[76] Inventor: **Robert T. Manor,** Box 95, Salmonia, Ind. 47381

[22] Filed: **Mar. 14, 1973**

[21] Appl. No.: **341,318**

[52] **U.S. Cl.** **91/413,** 91/467, 137/596

[51] **Int. Cl.** **F15b 11/00**

[58] **Field of Search** 91/467, 413; 137/596

[56] **References Cited**

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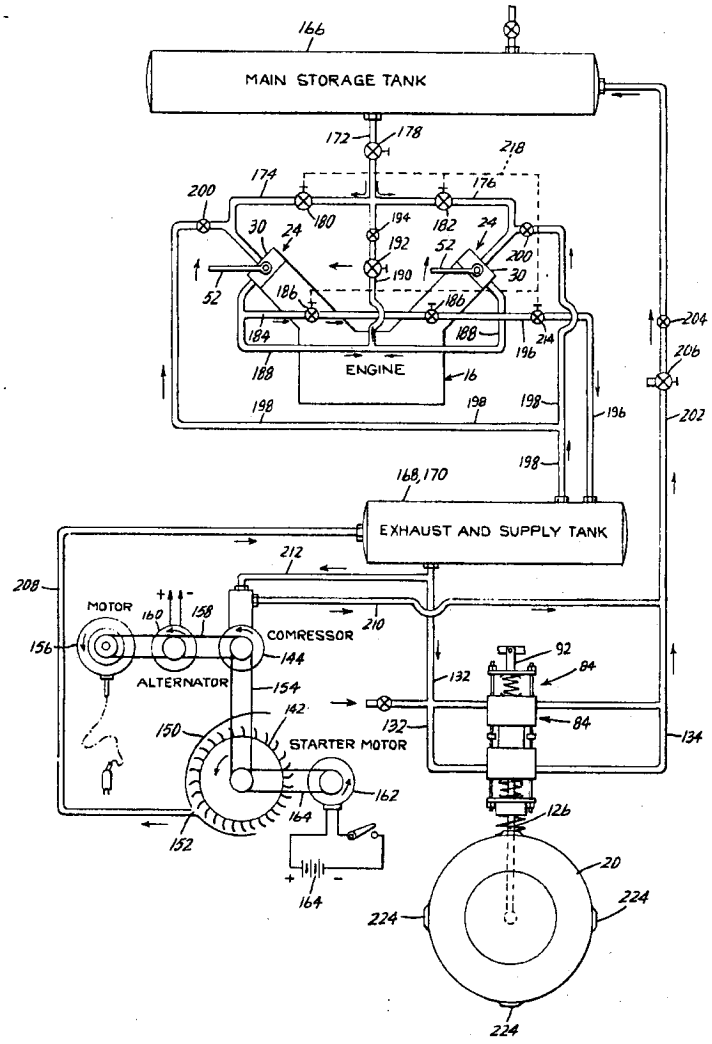
3,774,634	11/1973	Bonney	137/596

Primary Examiner—Edgar W. Geoghegan
Assistant Examiner—William F. Woods
Attorney, Agent, or Firm—Gust & Irish

[57] **ABSTRACT**

For use in an air operated, reciprocating engine, a valve mechanism for controlling mode of engine operation as either a prime mover or compressor as well as direction of operation. The valve mechanism includes a spool valve rotatably mounted inside a sleeve valve, both having a plurality of passages alternatively registerable for determining mode of operation. The sleeve valve is rotatably mounted in a head block having registerable passages communicating with the pistons.

7 Claims, 19 Drawing Figures



United States Patent [19]

Manor

[11] **3,980,152**

[45] **Sept. 14, 1976**

[54] **AIR POWERED VEHICLE**

[76] Inventor: **Robert T. Manor,** P.O. Box 95, Salmonia, Ind. 47381

[22] Filed: **Apr. 5, 1974**

[21] Appl. No.: **458,178**

Related U.S. Application Data

[62] Division of Ser. No. 341,318, March 14, 1973.

[52] **U.S. Cl.** ..... **180/66 B;** 267/65 D; 417/211; 417/231

[51] **Int. Cl.²** **F16F 11/30**

[58] **Field of Search** ..... 267/64 R, 65 R, 65 D; 280/106, 5; 417/211, 231; 180/66 B, 66 R; 60/484 C; 91/413; 137/596

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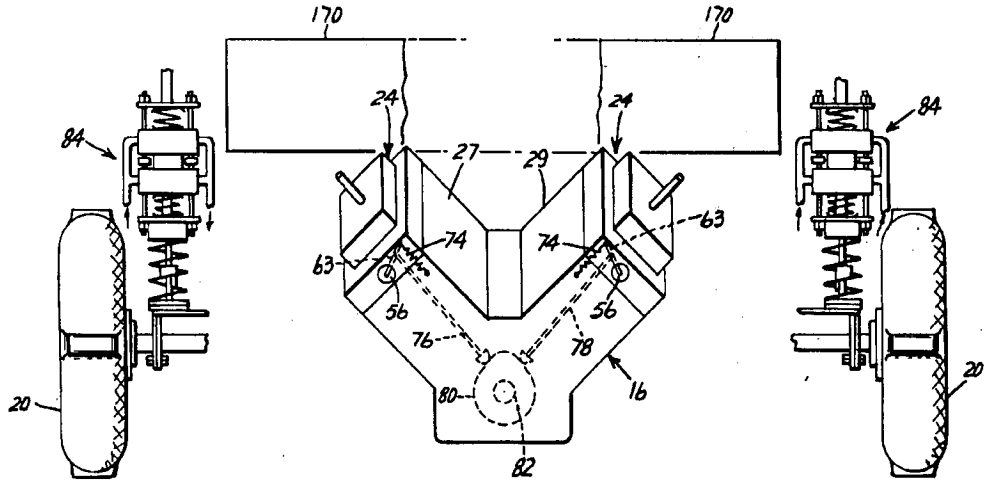
3,774,634	11/1973	Bonney	137/596

Primary Examiner—James B. Marbert

[57] **ABSTRACT**

This invention relates to an air powered vehicle including a chassis and wheels to which is connected an airpowered, reciprocating piston engine having intake and exhaust systems. A suspension type compressor is operatively connected between a wheel and the chassis whereby vertical movement of the wheel due to unevenness of the road or bumps provided on the wheel causes the compressor to operate and provide compressed air. This compressor is provided with inlet and exhaust ports connected, respectively, to a reservoir, whereby operation of the compressor pumps air to the reservoir for operation of the engine.

8 Claims, 19 Drawing Figures



U.S. Patent Sept. 14, 1976 Sheet 1 of 6 3,980,152

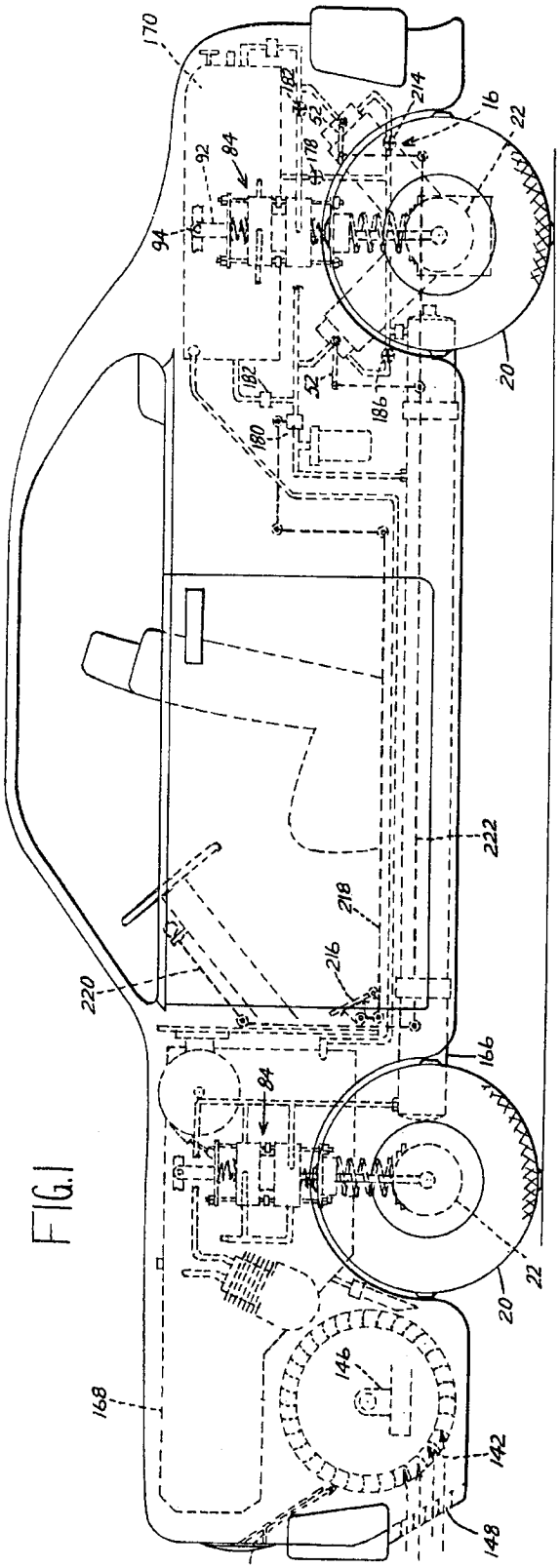


FIG.1

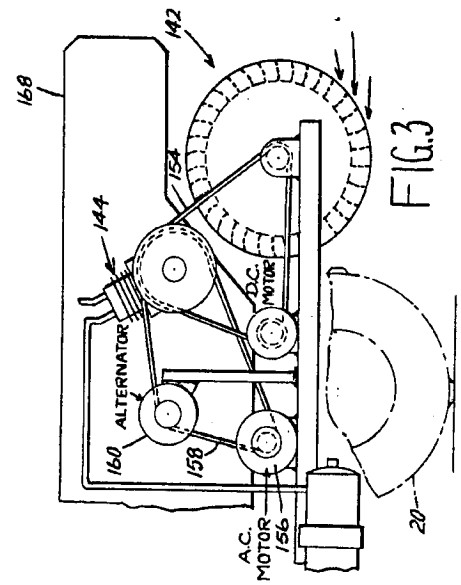


FIG.3

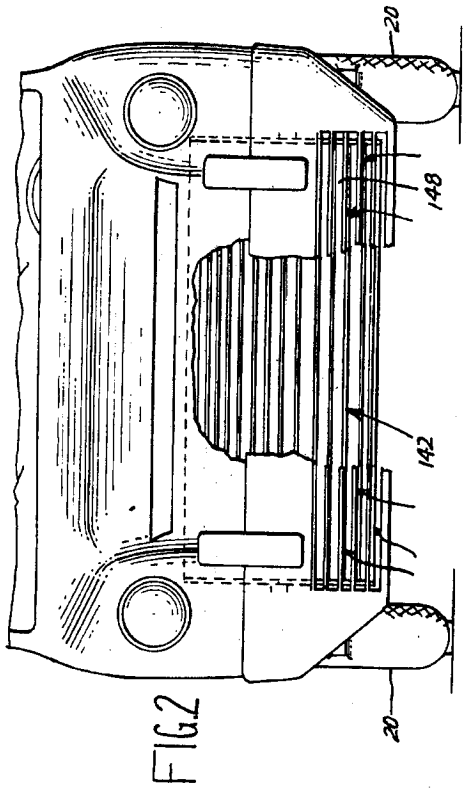
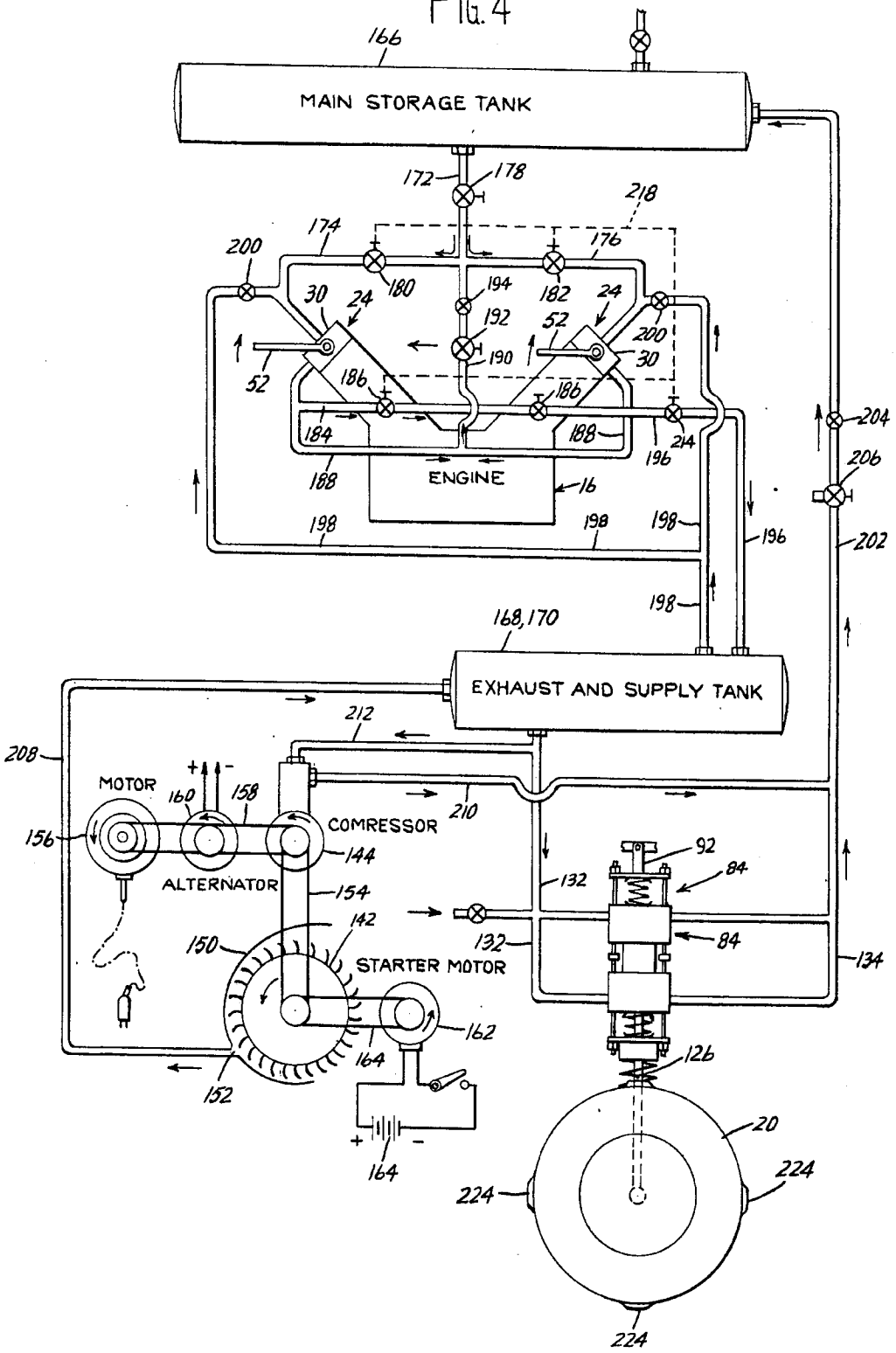


FIG.2

FIG. 4


MAIN STORAGE TANK
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ENGINE
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168,170
EXHAUST AND SUPPLY TANK
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208
MOTOR
160
158
COMRESSOR
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ALTERNATOR
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FIG.5

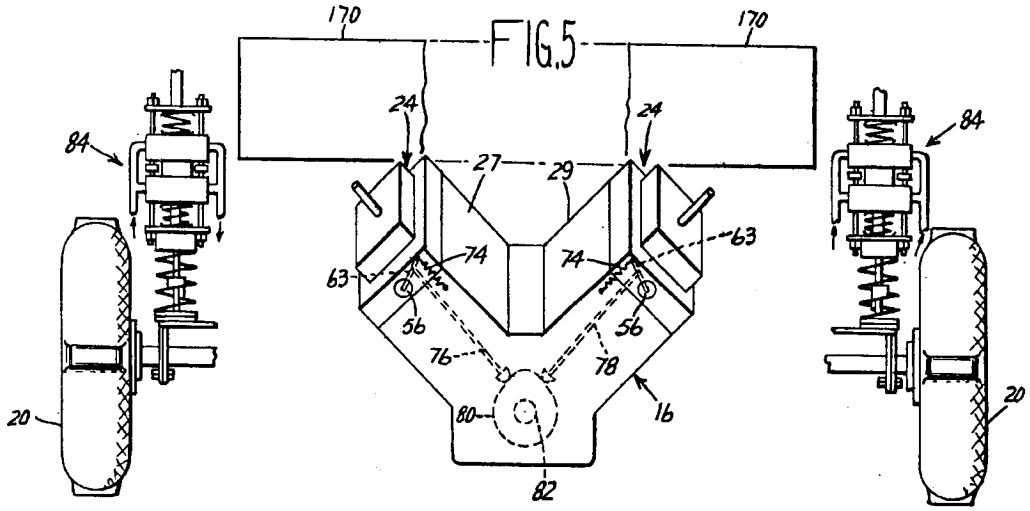
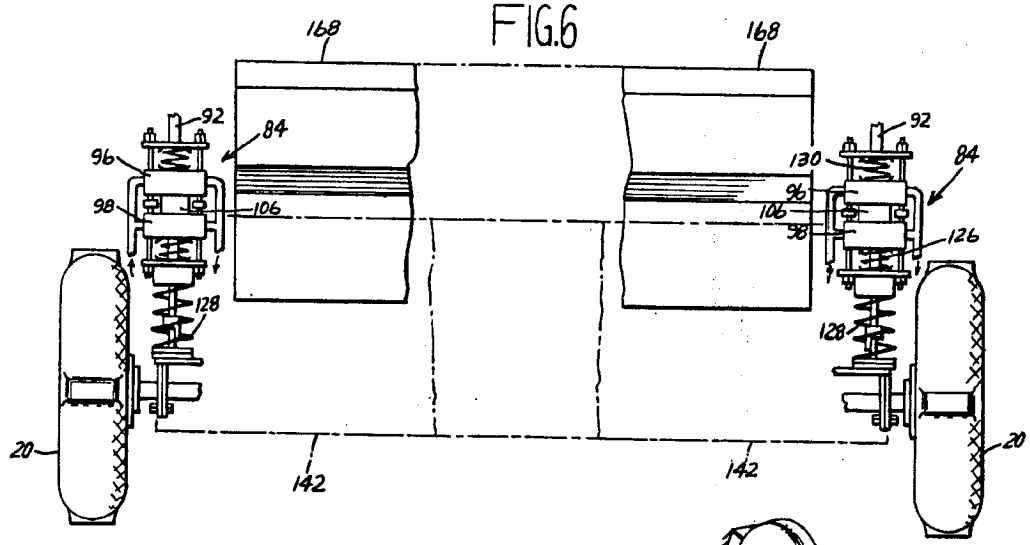


FIG.6



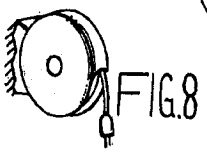


FIG.8

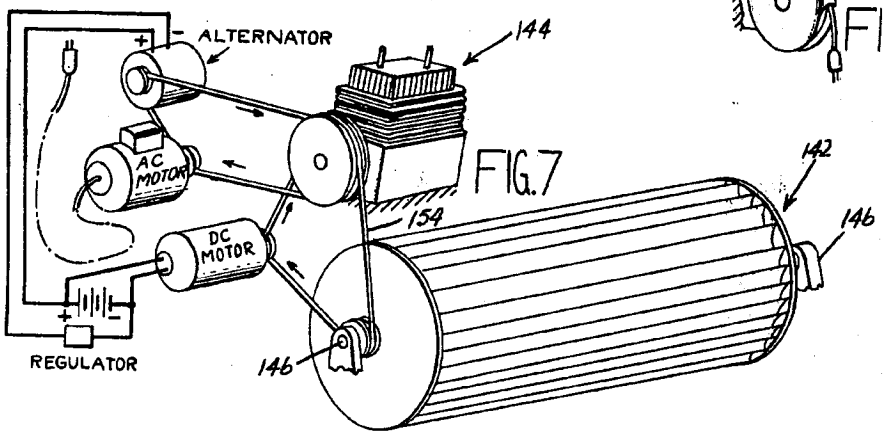


FIG.7

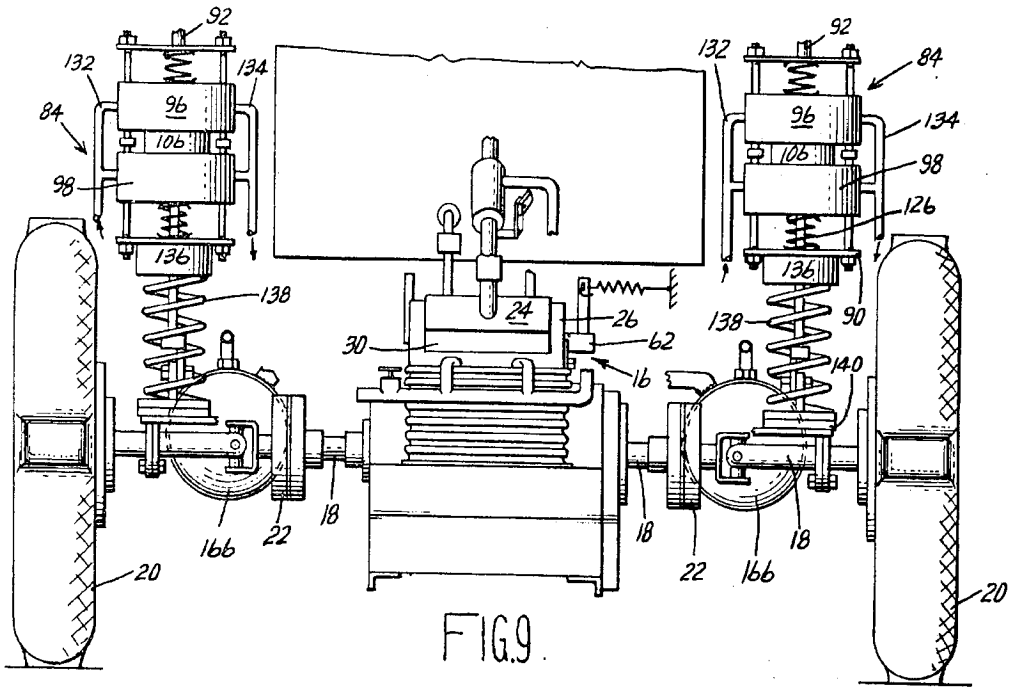

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FIG.9.

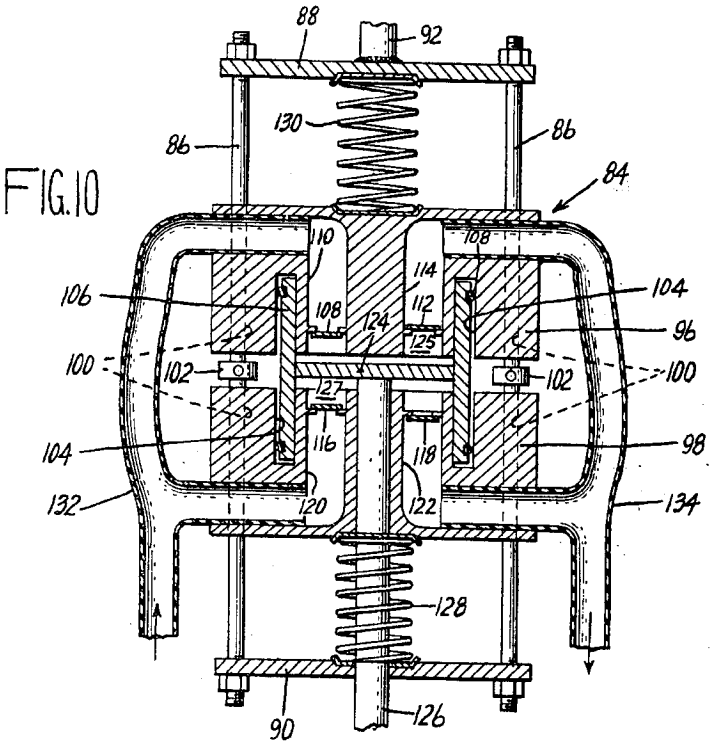
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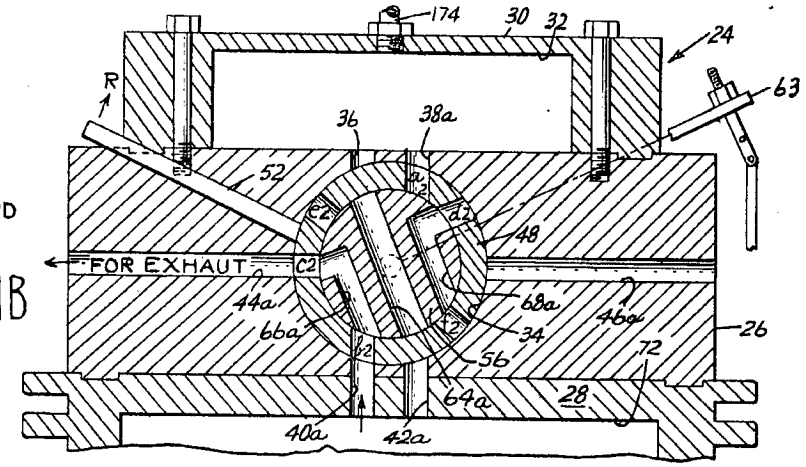
FIG.10

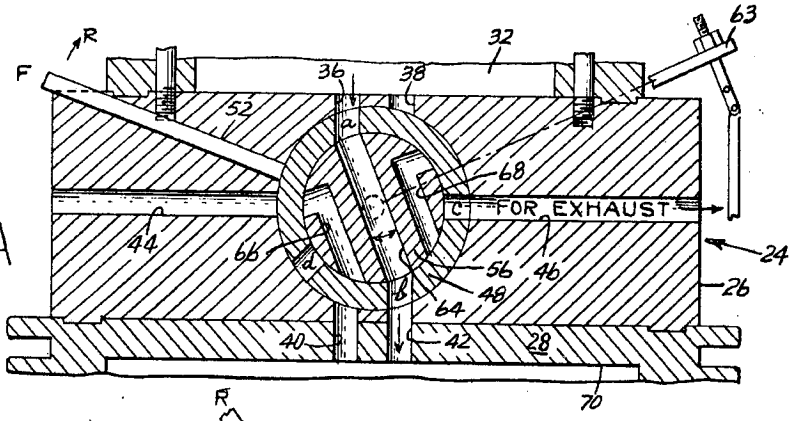
CYL #2
FORWARD
EXHAUST

FIG. 11B



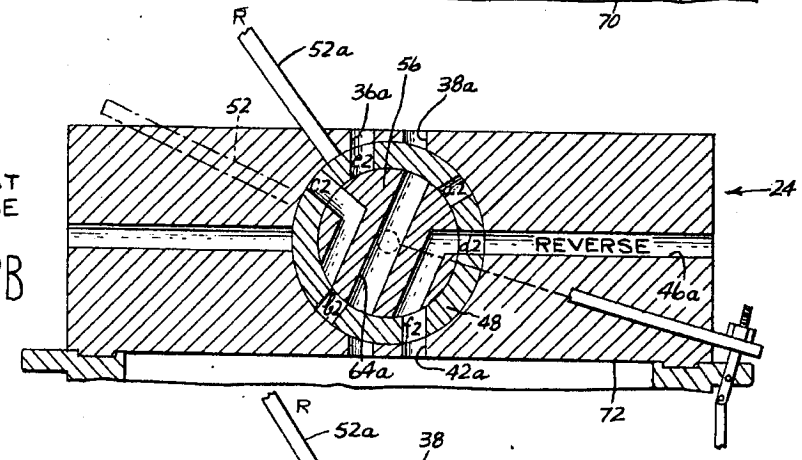
CYL #1
INTAKE
FORWARD

FIG. 11A



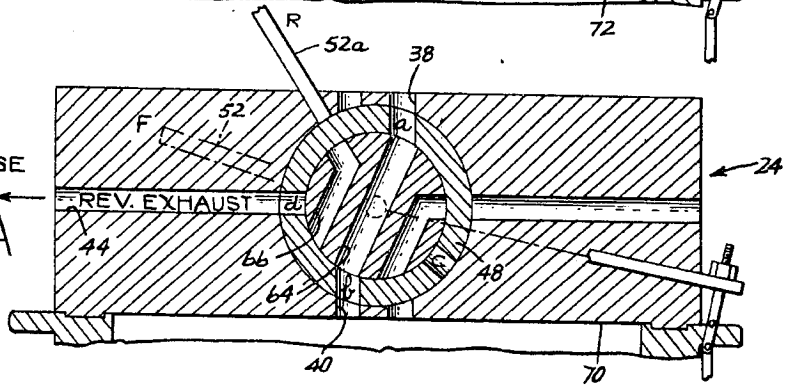
CYL #2
EXHAUST
REVERSE

FIG. 12B



CYL #1
INTAKE
REVERSE

FIG. 12A



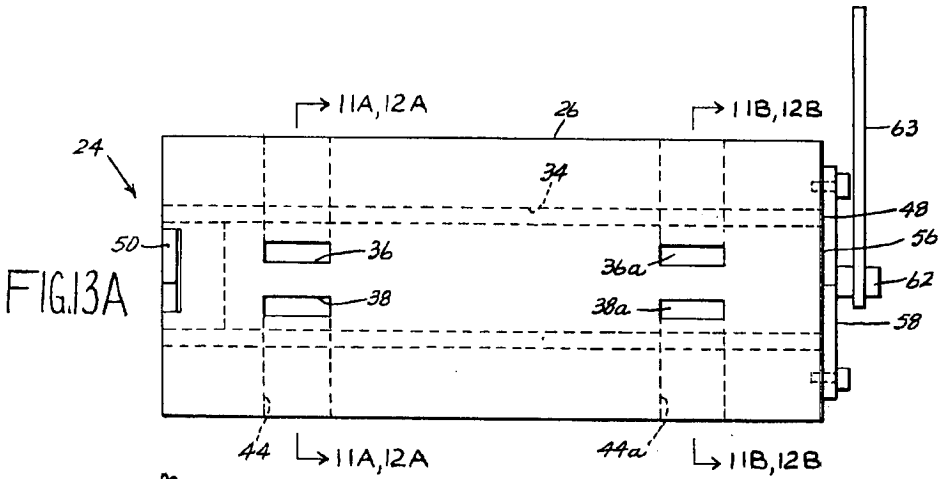


FIG.13A

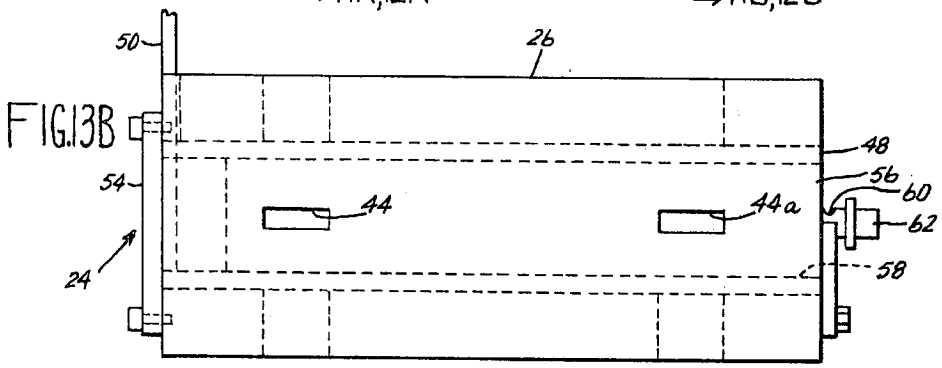


FIG.13B

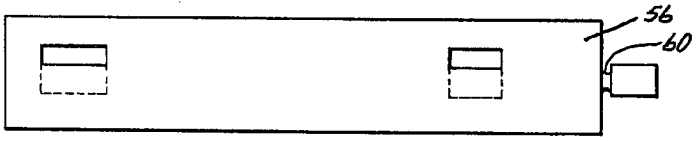


FIG.13C

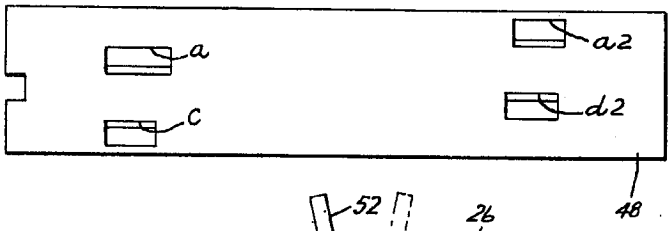


FIG.13D

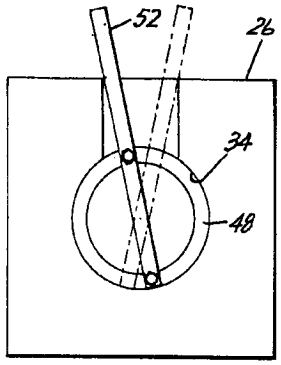


FIG.14

AIR POWERED VEHICLE

This is a divisional of application Serial Number 341,318, filed March 14, 1973.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates generally to vehicles and more particularly to a vehicle that operates from gaseous fluid such as air under pressure. More specifically, means are provided for generating air pressure from vertical motions of the vehicle.

SUMMARY OF THE INVENTION

In accordance with the broader aspects of this invention there is provided an air powered vehicle having a chassis and wheels. An air powered engine having intake and exhaust systems is mounted on the chassis and has a driving connection with the wheels. A first reservoir of gaseous fluid under pressure is connected to the intake system for operating the engine. Means are provided for regulating the flow of the fluid to the intake system for controlling the operation of the engine.

A second reservoir is connected to the exhaust system for receiving spent air, conduit means being connected between the second reservoir and the intake system. This conduit means is provided with a check valve which limits the flow of air in only the direction from said second reservoir to said intake system.

A suspension-type compressor is operatively connected between a wheel and the chassis, whereby relative vertical motion between the wheel and the chassis will cause operation of the compressor. This compressor is provided with inlet and exhaust ports connected, respectively, to said second and first reservoirs, whereby operation of the compressor pumps air from the second reservoir to the first reservoir.

Means are provided for disconnecting the flow of fluid from the first reservoir to the intake system and connecting the exhaust system to the first reservoir whereby the engine may serve as a compressor for delivering air under pressure to the first reservoir.

It is an object of this invention to provide an air powered vehicle in which pressure air is uniquely generated from the vertical movements of the vehicle.

Still another object of this invention is to provide a suspension type compressor capable of generating air under pressure due to the relative vertical motion of the vehicle suspension system.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation of a typical vehicle of this invention with certain of the mechanism being shown in phantom;

FIG. **2** is a front elevation thereof partially broken away for clarity of illustration;

FIG. **3** is a partial side view of the fan compressor mechanism mounted in the front end of the vehicle of FIG. 1;

FIG. **4** is a diagrammatic illustration of the fluid pressure system used in the vehicle of FIG. 1;

FIG. **5** is a diagrammatic view taken from the rear of the vehicle of FIG. 1 showing the reciprocating piston engine in perspective and rotated 90° from its normal position;

FIG. **6** is a fragmentary front view of the vehicle of FIG. 1 showing the position of one of the air tanks;

FIG. **7** is a diagrammatic perspective view of the compressor system mounted in the front end of the vehicle;

FIG. **8** is a perspective of the electrical power cord housing and retriever;

FIG. **9** is a fragmentary rear view of the vehicle with the body removed;

FIG. **10** is a longitudinal sectional view of the suspension type compressor;

FIGS. **11A** and **11B** are cross-sections of different parts of the engine valve mechanism in position for forward operation;

FIGS. **12A** and **12B** are similar cross-sections but with the parts shown in position for reverse operation of the engine;

FIGS. **13A** and **13B** are top and side views, respectively, of the valve mechanism;

FIG. **13C** is a side view of the spool valve used in the mechanism of the preceding figure;

FIG. **13D** is a side view of the sleeve valve used in the valve mechanism; and

FIG. **14** is an end view of the mechanism of FIGS. **13A** and **13B** showing the directional control lever.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings and more particularly to FIG. **1**, a vehicle which includes a conventional body, chassis, wheels, suspension system, steering and the like has mounted in the rear end thereof an air powered, reciprocating-piston engine generally indicated by the numeral **16**. The engine **16** has its crank shaft (not shown) directly connected to the drive axle **18** (FIG. **9**) which in turn is connected to the wheels **20** via two slip clutches **22** which permits one wheel **20** to rotate relative to the other wheel during turning motion of the vehicle.

The engine **16** is conventional in the respect that it corresponds to the usual reciprocating-piston gasoline engine having four cylinders in two banks of two cylinders each in a V configuration as shown more clearly in FIG. **5**. Conventional are the piston and cylinder assemblies, the piston rods, the crank shaft, the block and the like. However, the valve mechanism for controlling the intake and exhaust cycles is different as is the cam mechanism for operating the same. Such valve mechanism is shown in more detail in FIGS. **11** through **14**.

In general one valve mechanism **24** is provided for each of the two cylinder banks **26** and **28** (FIG. **5**). Since both valve mechanisms **24** are constructed the same, a description of one will suffice for both.

Referring to FIGS. **11** through **14**, the valve mechanisms **24** each include a body **26** in the form of a rectangular steel block adapted to be securely bolted in fluid-tight relation to the heads **28** of the engine cylinders and have securely bolted thereto also in fluid-tight relation a housing **30** formed of a block of steel having a cavity or plenum **32** therein.

The block **26** for number one cylinder, otherwise indicated by numeral **70**, is provided with a cylindrical

cavity 34 and communicating intake passages 36, 38, cylinder passages 40, 42 diametrically opposed exhaust passages 44, 46.

That portion of the valve mechanism 24 for number two cylinder 72, is identically arranged with components thereof indicated by the same numerals with the suffix "a" added.

Close fitting in fluid-tight relation in the cylindrical cavity 34 but rotatable therein is a cylindrical sleeve valve or sleeve 48 having a series of rectangular ports indicated by the letters *a*, *b*, *c*, and *d* for cylinder 70 as shown in FIG. 11A and *a*2, *b*2, *c*2, *d*2, *e*2 and *f*2 for cylinder 72 as shown in FIG. 11B. The particle angular relationships between these ports are shown in FIGS. 11A and 11B and will be explained further later. These ports are rectangular to coincide in size and shape with the ports 36 through 46. As viewed in FIGS. 13A through 13D and 14, the block 26 has a rectangular notch 50 formed in one end thereof which communicates with the cavity 34, this notch receiving a lever 52 secured to the end of the sleeve valve 48 in notches provided therefor. A suitable plate 54 (FIG. 13B) is bolted to the left-hand end of the block 26 so as to retain the sleeve valve 48 against leftward movement. The right-hand end of the sleeve 48 is flush with the right end of the block 26.

A cylindrical spool valve 56 is rotatably received within the sleeve valve 48 with a close tolerance, fluid-tight fit. As shown more clearly in FIGS. 13A and 13B, a plate 58 is bolted to the right-hand end of the block 26 and is provided with a semi-circular cutout having a semi-circular tongue (not shown) which slidably fits into an annular, coaxial groove 60 in the protruding shaft 62 of the spool valve 56. The plate 58 thereby retains the spool valve 56 against end-wise movement and furthermore retains the sleeve valve 48 from rightward movement.

The spool 56 and the sleeve valves 48 are operated between two different angular or rotated positions, the sleeve 48 (see FIG. 14) being swingable from a first position represented by the dashed-line position of the lever 52 (FIGS. 12A, 12B) to a second position represented by the solid line lever 52*a*. The spool 56 has a first angular position as shown in FIG. 11A and a second angular position as shown in FIG. 12A. For moving the spool valve 56 to these two positions is provided a rocker arm 63 secured to the shaft extension 62 (see FIGS. 13A and 13B).

The spool valve 56 has two sets of transverse passages therein, the sets being axially spaced apart to register with the cylinders 70 and 72 of one of the V-engine banks, such as with ports 36, 38 of one set and 36*a*, 38*a* of the other set. Thus, a description of one set will suffice for both. Referring first to FIG. 11A, the spool valve 56 has a rectangular diametral passage 64 which communicates with the rectangular ports *a* and *b* in the sleeve valve 48 and the passages 36 and 42 in the block 26. Two other passages 66 and 68 on opposite sides of the passages 64 have right angle bends therein as shown and are positioned to communicate with the various ports in the sleeve 48 as shown. In FIG. 11A, neither of the passages 66 and 68 communicate with any sleeve 48 ports. However, in FIG. 11B, passage 66 is shown communicating with the ports *b*2 and *c*2 as well as passages 40*a* and 44*a*, respectively. It may now be stated that FIG. 11A shows the position of the valve mechanism for forward engine operation with cylinder number one (70) on the intake stroke and FIG. 11B with cylinder number two (72) on the exhaust stroke.

By moving the spool 56 clockwise to its second position as shown in FIGS. 12A and 12B, with lever 52 remaining in the solidline position of FIGS. 11A, 11B, in FIG. 11A for cylinder number one passage 68 registers with ports *b* and *c* so as to provide an exhaust for cylinder 70, for continuing forward operation of the engine. In FIG. 11B cylinder number two (72) is shown as having ports *a*2 and *b*2 connected by passages 64 with none of the other spool passages connecting with any ports.

It may now be stated that air under pressure is admitted to the plenum 32 from which it may flow through the passages 36, 38, 36*a* and 38*a* through the respective spool 56 passages to the cylinders 70 and 72 as determined by the position of both the sleeve 48 and the spool 56.

Further explanation of operation and port arrangement will now be given for forward operation of the engine as determined by the position of the lever 52 as shown in FIGS. 11, 11B. Referring again to FIGS. 11A and 11B, cylinder 70 of FIG. 11A is on the intake stroke, air pressure from the plenum 32 passing through passage 36, port *a*, passage 64, port *b* and passage 42 into the cylinder 70. Simultaneously therewith, cylinder 72 of FIG. 11B is exhausting with the piston being on the up stroke, exhaust air passing out of the passage 40*a*, port *b*2, passage 66, port *c*2, and exhaust passage 44*a*.

With the spool 56 next swung to its rightward position as shown in FIGS. 12A and 12B, but with the lever 52 in the position of FIGS. 11A, 11B, cylinder 72 (FIG. 11B) intakes through passage 38*a*, port *a*2, passage 64, port *b*2 and passage 40*a* with the piston in cylinder 72 thereby being on its down stroke, while cylinder 70 is exhausting with the piston on the upstroke through passage 42, port *b*, passage 68, port *c* and exhaust passage 46. Thus, by the spool valve 56 oscillating between the two angular positions, cylinders one (70) and two (72) are operated alternately on the intake and exhaust strokes.

For reverse operation of the engine, reference is made to FIGS. 12A and 12B. The lever 52 is moved from the dashed line position to the full line position 52*a* thereby swinging the sleeve valve 48 to the position shown. In this position, the cycle of operation as between cylinders 70 and 72 reverses such that cylinder number one (70) now intakes through passage 38, port *a*, passage 64, port *b*, and passage 40 into cylinder 72. Simultaneously therewith, cylinder number two (72) is exhausting from cylinder 70 through passage 42*a*, port *f*2, passage 68*a*, port *d*2 and out of exhaust port 46*a*. With the spool valve moved to its opposite position as shown in FIGS. 11A and 11B, cylinder 70 (FIG. 12A) will exhaust through passage 40, port *b*, passage 66, and port *d* and out of exhaust passage 44. Simultaneously therewith, cylinder 72, (FIG. 12B) which is also cylinder number two, is intaking through passage 36*a*, port *e*2, passage 64*a*, port *f*2, passage 32*a*, into cylinder 70.

Thus, the position of the sleeve valve 48 as determined by operation of the lever 52 determines whether the engine will operate either forwardly or reversely. The rapid rocking motion of the spool valve 56 between the two illustrated positions determines the intake and exhaust strokes of the cylinders.

Referring more particularly to FIGS. 4 and 5, the engine thereshown is of "V-4" configuration having

two banks 27 and 29, with two cylinders 70 and 72 being in each bank. Thus, cylinders one (70) and two (72) may be considered to be in the left bank as viewed in FIG. 5 while cylinders three (70) and four (72) will be in the right bank.

The rocker arms 63 on the two valve spools 56 are spring biased by means of suitable tension springs 74 (FIG. 5) such that clockwise force is exerted on the left-hand spool 56 and counterclockwise force on the right-hand spool 56. Operatively connected to each of the rocker arms 63 are two push rods 76 and 78 which ride on a rotatable cam 80 secured to the engine crank shaft 82. As the cam 80 rotates, both of the rocker arms 63 will be swung between two extreme positions as shown in FIGS. 11 and 12, thereby placing the spool valve 56 in position for the intake and exhaust strokes, respectively.

The cam 82 is so shaped and the ports and passages in the valve mechanism 24 so positioned that the piston movement in one bank 27 is 90° out of phase with the piston movement in the other 29. The pistons in one bank 27, 29 are 180° out of phase with each other thereby providing for concurrent exhaust and intake stroking. The cam 80 is so shaped, and the valve mechanisms 24 with the ports and passages therein so positioned that the engine cylinders will "fire" according to a sequence of one, three, two, four. Thus, with piston movement, crank shaft rotation as a result thereof, and cam 80 rotation, the spool valves 56 are oscillated between their intake and exhaust positions for admitting pressure air and providing for exhaust in proper, timed sequence.

Referring now to FIGS. 1, 9 and 10. description of the suspension type compressors 84 will be given. Four such compressors 84 are used, one for each of the four vehicle wheels, such that a description of one compressor 84 will suffice for all. A rectangular, rigid frame includes two upright, horizontally spaced rods 86 having two cross bars 88 and 90 secured to the opposite ends thereof as shown. Secured to the upper cross bar 88 is a tie rod 92 secured rigidly at the end 94 (FIG. 1) to a part of the vehicle frame. Slidably mounted on the rods 86 are two heads 96 and 98 in vertically spaced relation which conform generally to rectangular blocks which are preferably formed of steel. Each of the heads 96 and 98 are provided with bores 100 which closely slidably receive the respective rods 86 whereby the heads 96 and 98 may move vertically on the rods. Spacer blocks 102 on the rods 86 between the heads 96, 98 provide minimum spacing therebetween.

Both heads 96, 98 have formed therein an elongated cylindrical groove 104 adapted slidingly to receive a tubular member 106 having O-ring seals 108 for providing a sliding, sealing engagement with the outer cylindrical walls of the grooves 104. Within each head 96, 98 are provided two valve assemblies, one of these being for intake and the other exhaust. In the head 96 the intake valve is indicated by the numeral 108 in the form of a one-way check valve mounted in a passage 110 in the head. Another valve 112 for exhaust, also being a one-way check valve, is mounted in the passage 114. In the head 98 are two similar valves 116 and 118 in the two passages 120 and 122, respectively.

A piston is reciprocally positioned in the cylinder 106 and has a coaxially extending piston rod 126 secured thereto which is slidably sealingly received by a close fitting coaxial bore in the head 98. The piston rod 126 is adapted to be operatively secured at its distal end (see FIG. 9) to the vehicle axle 16.

A compression spring 128 is interposed between the cross 90 and head 98 as is another compression spring 130 between the cross bar 88 and the head 96. These two springs 128, 130 yieldably urge the heads 96, 98 toward each other into abutting engagement with the respective ends of the tubular cylinder 106. Movement of the heads 96, 98 on the rods 86 is, as explained previously, limited by the stops 102.

Connected to the passages 110, 120 is a flexible conduit 132, another flexible conduit 134 being connected to the other two passages 114 and 122.

For the suspension compressor 84, the conduit 132 constitutes the air intake and the conduit 134 the exhaust. Since the rod 92 is secured to the vehicle chassis, for purposes of explaining the operation of the compressor, the rod 92 may be regarded as stationary with respect to the movable piston rod 126 which is secured to the vehicle axle which obviously moves vertically as the wheels 20 move over uneven terrain.

Thus, as the piston rod 126 moves vertically from its illustrated position (FIG. 10), any air trapped in chamber 125 will be exhausted past check valve 112 out of conduit 134, the check valve 108 remaining closed since it will open only for air flow in the opposite direction. Simultaneously therewith, check valve 116 will be unseated thereby to admit air through conduit 132 into the chamber 127. On the down stroke of piston 124, air trapped in chamber 127 is forced through check valve 118, valve 116 remaining closed, and out of the exhaust conduit 134. Simultaneously, air is drawn through valve 108 into chamber 125, check valve 112 remaining closed. Thus, as the piston rod 126 reciprocates, air will be pumped from the intake conduit 132 outwardly through the exhaust conduit 134.

If the vehicle wheel 20 should encounter a sizable bump which causes corresponding upward movement of the piston rod 126, the piston 124 will engage the underside of the head 96 causing it to move upwardly slightly against the force of spring 130. Conversely, should the piston 124 move downwardly sufficiently to engage the head 98, the latter will move downwardly against the force of its spring 128. Any such movement of the heads 96 and 98 will correspondingly provide an increase in the size of the respective chamber 125, 127 whereby on that stroke a larger volume of air will be taken in and exhausted via the conduits 132, 134, respectively.

As seen in FIG. 9, the cross bar 90 is secured to a suitably, rigid pad 136 through which the piston rod 126 projects, a helical compression spring, which serves as the spring suspension for the vehicle, bearing thereagainst and against another pad 140 which is secured to the axle 18 as shown. Thus, the load of the vehicle rests primarily on the springs 138 which permit relative movement between the axle 18 and the vehicle chassis such that the piston 124 in the compressor 84 may reciprocate vertically.

Now referring to FIGS. 1 through 3, 7 and 8, compressor system mounted in the front end of the vehicle will be described. This system includes a compressor type fan, generally indicated by the numeral 142, the fan in this instance being of the squirrel cage type, and a conventional reciprocating piston compressor indicated by the numeral 144. The fan 142 is generally cylindrical, having the usual circumferentially arranged blades, and is journalled in bearings 146 to rotate about

its axis arranged parallel to the axles of the vehicle. As shown in FIG. 1, the fan 142 is exposed forwardly to air flow through the front of the vehicle via an open grill 148 such that during forward motion, air flow causes rotation of the fan 142. As shown diagrammatically in FIG. 4, the fan 142 is provided with the usual hood 150 having an outlet 152 through which air pumped by the fan 142 may escape from the chamber between the hood 150 and fan 142.

The compressor 144 is fixedly mounted on a stationary part of the vehicle, and is driven by a belt 154 connected to the fan 142. Thus, as the fan 142 rotates, the compressor 144 will be operated to produce compressed air. Also mounted on the vehicle chassis is an alternating current motor 156 drivingly connected to the compressor 144 by means of a belt 158. A conventional alternator 160 mounted on the chassis is also drivingly connected to both the motor 156 and compressor 144 by means of the belt 158.

A starter motor 162 mounted on the vehicle chassis and operative from a conventional vehicle storage battery is drivingly connected to the fan 142 and compressor 144 by means of a belt 164. Thus, the compressor 144 may be driven by any one or more of three different power sources, the fan 142 and the two motors 156 and 162. For operating the motor 162, the conventional electrical circuit to a storage battery 164 is utilized.

Referring now more particularly to FIGS. 1, 3, 5 and 6, additional components used in the fluid power operating system will be described. Mounted rigidly to the underneath side of the vehicle chassis are two main reservoirs or storage tanks (FIG. 9) connected in parallel by suitable piping. In the front end of the vehicle is mounted a storage tank 168 and in the rear another storage tank 170. All of the storage tanks, of course, are fixedly secured in place in the vehicle.

The various parts and mechanisms thus far described are connected together in a fluid system shown diagrammatically in FIG. 4. The reservoir or main storage tank 166 is of such strength as to contain air at relatively high pressure, such as 100 to 150 pounds per square inch. Outlet piping connected to this tank includes a section 172, and two branches 174 and 176, these latter branches being connected to the plenum housing 30 of the two valve mechanisms 24 (FIGS. 11 and 12). A main control valve 178 in the section 172 may close or open in degrees the latter as may be desired. Two other control valves 180 and 182 connected in series with the two branches 174 and 176, respectively, are manually controllable to determine the flow of pressure fluid through the branches. Thus, with valves 178, 180 and 182 fully opened, air at the pressure in the tank 166 is communicated to the plenums 32 for the engine cylinders.

The exhaust passages of the valve mechanisms 24 as shown in FIGS. 11 and 12 are connected together by a pipe 184 having a manually controlled regulating valve 186 in a series therewith. Another section of pipe 188 connects between the exhaust passages of the valve mechanisms 24 and also back to the pipe section 172 via a branch 190. In this branch 190 is a shut-off valve 192 and a one-way check valve 194 which permits flow only in the direction upward, or in other words, toward the tank 166. The valve 192 is vented to atmosphere such that air in the system may be vented.

Another pipe 196 is connected to the exhaust system of the two valve mechanisms 24 and to the storage tanks 168, 170 as shown. Another pipe 198 is connected to tanks 168, 170 back to the intake side of the two valve mechanisms in parallel with the branches 174, 176. One-way check valve 200 are provided in the lines 198 as shown to permit flow in only the direction from the tanks 168, 170 to the plenums 32 of the valve mechanisms.

Also connected to the supply tanks 168, 170 is the conduit 132 which leads to the suspension compressor 84. Suffice it to say at this point all four of the suspension compressors 84 are connected in parallel such that there would be four lines 132 connected to the supply tanks 168, 170. The exhaust conduit 134 of the compressor 84 is connected by means of a line 202 back to the main storage tank 166, a one-way check valve 204 therein permitting flow only in this direction, and a manually controlled shut-off valve 206 being operable to close off the line 206 and furthermore vent the pressure in the system to atmosphere if desired.

The outlet 152 from the fan compressor 142 is connected by means of a pipe 208 to the supply tanks 168, 170 while the exhaust side of the compressor 144 is connected by means of the line 210 to line 202, with the input thereto being connected by a line 212 to the tanks 168, 170.

A manually controlled valve 214 is connected in the line 196 leading from the exhaust side of the engine 16, and this valve is connected by suitable mechanical linkages to the other valves 180, 182 and 186 for operating the engine 16. Such engine control is shown in one form in FIG. 1 as including an accelerator pedal 216 connected by means of a control line, such as a Bowden cable, to the valves 174, 176, 186 and 214 such that all these valves may be operated in the same manner simultaneously. A Bowden cable is well known, consisting of a stiff wire reciprocably contained in a tubular supporting sheath, such cable being conventional in operating carburetor chokes and the like of internal combustion engines. To start the engine 16, the valve 178 is first opened following which the pedal 216 (FIG. 1) is operated to open the valves 180, 182, 186 and 214. Air under pressure is admitted to the plenums 32 in the valve mechanisms 24, to cause operation of the engine as already explained. Spent exhaust fluid passes to the tanks 168, 170 via the line 196 where it is stored until it is pumped therefrom back to the main storage tank.

For braking the vehicle, assuming that the vehicle is in forward motion, the pedal 216 is operated reversely to close the valves 180, 182, 186 and 214 in which event the engine 16 becomes a compressor, withdrawing air from the supply tanks 168, 170 via the lines 198 and pumping it back to the storage tank 166 via the line 188, branch 190, and through the check valve 194. Thus, during coasting or down-hill movement of the vehicle, the engine 16 may be used as a compressor for producing compressed air which is returned to the storage tank 166.

For reversing the movement of the vehicle, a control 220 in the cab is operated, this control being connected by means of a Bowden line 222 to the levers 52 (FIGS. 1, 11 and 12), moving these levers 52 to their reverse positions. As explained previously in connection with the valve mechanisms of FIGS. 11 and 12, pressure air in the plenums 32 will cause reverse operation of the engine 16.

During motion of the vehicle over uneven terrain, the wheels 20 will move vertically in the usual manner

causing corresponding movement of the pistons **124** (FIG. **10**) in the suspension compressors **84**. This results in withdrawing air from supply tanks **168, 170,** compressing and exhausting it through conduit **134** and line **202** back to the main storage tank **166.** For facilitating this pumping action, circumferentially spaced bumps **224** are applied to the peripheries of the wheels **20** whereby reciprocatory movement of the pistons **124** is assured.

The compressors **142** and **144** are operated primarily from the air flow induced by forward motion of the vehicle. This motion rotates the fan **142** which in turn operates the compressor **144.** The fan **142** with its shroud or hood **150** produces some air flow back to the tanks **168, 170** via the line **207.** The compressor **144** operates to provide compressed air to the line **202** and back to the storage tank **166.**

When the compressed air in the system becomes depleted, operation of the motor **156** drives the compressor **144** for refilling the storage tank **166.** If alternating current power is not available, the D.C. motor **162** which operates from the vehicle battery **164** is energized for driving the compressor **144.** Simultaneously therewith, the fan **142** is operated, this assisting to a small extent the supplying of air to the system while the vehicle is stationary.

During operation of the vehicle, the alternator **160** is driven, and this is operatively connected to the storage battery **164** for maintaining the charge thereon.

When not in operation, for example at night in the garage, the motor **156** may be connected to an electrical outlet for the purpose of recharging the storage tank **166.** Necessary conventional automatic devices may be employed for cutting off the electrical motor **156** when the tank **166** has become suitably filled.

The vehicle is operated solely, in the preferred embodiment, by the use of compressed air initially stored in the tank **166.** The vehicle may be operated to move forwardly, rearwardly, and furthermore the engine may be used as a compressor during coasting, braking or down hill motion of the vehicle, thereby restoring spent pressure to the storage tank **166.** Vertical motion of the wheels is utilized for the purpose of operating the suspension pumps **84,** further replenishing the used energy taken from the storage tank **166.** Also during vehicle movement in coasting, braking or down hill, the fan **142** is operated when a sufficient velocity has been reached, for pumping air back into the system.

Inasmuch as the vehicle operates on compressed air, it is obvious that in contrast with the internal combustion engine, there will be less pollution of the atmosphere, it will not be necessary to use inflammable liquid, and the air which is used as fuel is ever present in the atmosphere. The engine itself uses a minimum of moving parts, is simpler in construction than its internal combustion counterpart and is more economical to produce and operate. Also, the engine will operate with less noise than is true of the gasoline engine.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. For use on a vehicle, a suspension type compressor comprising a cylinder device having a reciprocable piston which defines two pressure chambers therewith, a piston rod secured to said piston and extending axially therefrom, means for securing said cylinder device and piston between the frame and axle of a wheeled vehicle; said cylinder device including two separate heads arranged one above the other, means mounting said heads for limited relative movement, means yieldably urging said heads toward each other, and intake and exhaust valve means in each head responsive to reciprocation of said piston in said cylinder device for drawing gaseous fluid into and forcing such fluid out of said chambers.

2. The compressor of claim **1** in which said cylinder device includes a tubular element slidably sealingly fitted into companion grooves in the facing portions of said heads, each said head having two check valves therein communicating with respective ones of said chambers, one of each of said two valves being an intake valve and the other an exhaust valve, and intake and exhaust conduits connected, respectively, to said intake and exhaust valves.

3. The compressor of claim **2** in which said head-mounting means includes a rigid frame having two laterally spaced upright rods received by companion guide bores in opposite lateral portions of said heads, said frame having two cross bars secured to opposite ends of said rods, said yieldable means including two helical compression springs, respectively, interposed between said cross bars and the adjacent heads, said piston rod slidably passing through one head, a respective spring and one cross bar, said heads having facing surfaces which define opposite ends of said chambers, respectively, said piston being disposed between said facing surfaces thereby to move the heads against the respective spring, and stops on said rods, respectively, between said heads and engageable therewith upon predetermined relative movement of said rods and heads.

4. The compressor of claim **3** in which said heads are spaced apart and said stops being disposed in the space therebetween.

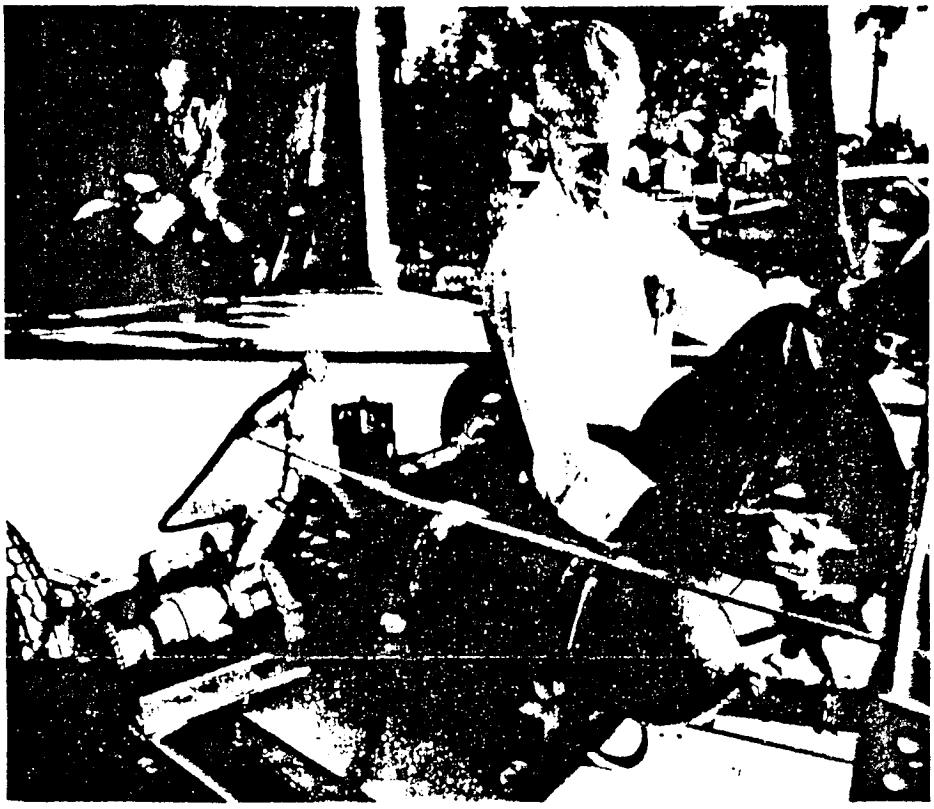
5. The compressor of claim **4** including two flexible conduits, each conduit having two branches, the two branches of one conduit communicating, respectively, with the intake valves in said heads and the two branches of the other conduit communicating, respectively, with the exhaust valves in said heads.

6. The compressor of claim **5** in which said intake and exhaust valve means in each head includes two passages communicating at common ends thereof with said chambers, respectively, the opposite common ends of said passages communicating with said branches, respectively, and check valves in said passages, respectively.

7. The compressor of claim **6** in which said passages in each head are spaced apart and elongated in parallelism with said tubular element, said conduits being flexible to accommodate relative motion of said heads.

8. The compressor of claim **7** including an axle connected to one of said piston and frame, a wheel on said axle, and said wheel having one or more raised portions on the periphery thereof whereby said piston is reciprocated relative to said tubular element as said wheel rolls over a level surface.

* * * * *



— Staff Photo by John Price

Inventor Claud Mead demonstrates how his miniature auto is powered by compressed air. Vehicle makes a muffled sputtering sound in motion.

COMPRESSOR FILLS TANK

Car Runs On 'Air Power'

Another picture — Page A-5

By CLIFF SMITH
Science Writer
The San Diego Union

The skeptical listener wants to turn his head and snicker when Claud F. Mead or one of his partners begins to describe the workings of their "air power" automobile.

A look at the vehicle compounds disbelief and adds to amusement. Outwardly it appears to be an ill-conceived cross between a go-cart and a Formula I racer.

The lumpy, fiberglass body is an atrocity of architectural design. One is seized by an impulse to look for pedals. The mechanics are reminiscent of a Rube Goldberg cartoon.

LIKE TOY BALLOON

"I got the idea, actually, watching a toy balloon," Mead explains. "You know how they will fly through the air in circles when the air is rushing out."

Then, just as politeness fails and you are about to guffaw, Mead jumps into his flivver and drives away.

The only thing propelling Mead briskly down Mt. Etna Drive was compressed air metered out of a diver's scuba bottle. A hose carried the air from the tank to a converted impact wrench, essentially a turbine engine. The torque imparted by the wrench was transferred to one rear wheel by a motorcycle drive chain.

Near the air tank was a simple air compressor. Mead showed how a gear can be engaged with another on the rear axle to turn the compressor and partially replenish the tank whenever the car is running downhill.

MOTOR STARTER

Connected to the other rear wheel was an electric motor powered by a single auto battery. This is used to set the prototype car into motion from a dead stop.

"In the year that we have been developing the car, it has been driven about 200 miles," Mead said. "I'm sure it will go at least 50 miles an hour. Of course you wouldn't want to drive this particular vehicle that fast. But, there is plenty of power."

Fred Y. Karasawa, one of Mead's partners and the owner of an oriental imports store on Balboa Avenue, explained how a full-size, production air car would have an air storage tank about three times larger than the scuba bottle in the prototype.

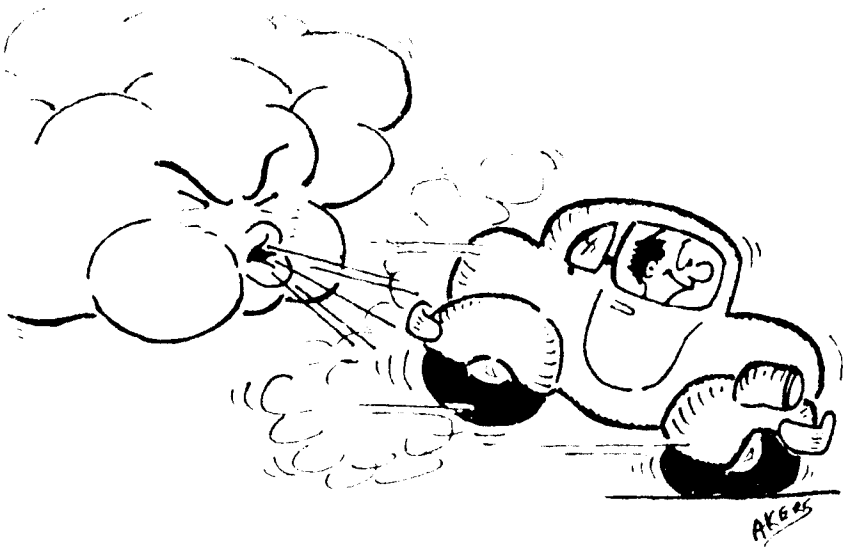
WEEK'S SUPPLY

"We calculate that the air supply would last about one week in typical around-town driving," Karasawa said. "On a long trip, the tank would have to be recharged after every 600 to 800 miles.

"I laughed, too, when Claud first told me about his idea. Now, I'm convinced that it will work."

Mead, an advertising designer, said a patent search revealed nothing quite like his design. Patents now are pending on the unique design features.

Mead said a production car would have a differential or automatic transmission and torque would be delivered to the wheels by a shaft, rather than chains. The electric motor would be retained but used only as an auxiliary power unit for emergencies when the air tank was exhausted.



Vacaville Reporter

VACAVILLE MAN HAS 'FOUND THE ANSWER'

An Engine That Runs on . . . Air?

Sunday, August 8, 1976

By TOM MAULDIN
Sports Editor

"It's the car of the future. There's absolutely no doubt in my mind," says Vacaville resident Raymond Starbard, inventor of an air-powered car.

That's right. Air-powered. No gas, no oil, no water. Just plenty of Mother Nature's free stuff.

"It's really simple when you get right down to it," says Starbard, who moved here recently from Sacramento. "The car's system is similar to a windmill in many aspects as its air intake is continually put to use, but the keys to the operation are my newly designed shock absorbers. Without them, the system is inadequate and unpractical."

Starbard's air-powered car is presently a 1966 Chevrolet Impala. He hopes to move the system into a smaller vehicle in the near future and is presently in the process of having the system, known as "power transmission unit" patented in every country in the world.

"I already have it patented in 42 countries and should be getting my U.S. patent any day now. It's been a long time coming and I'll be glad when the system is sold. It has me very nervous and irritable," added Starbard, who feels his invention has jeopardized his life on a number of occasions.

"You might be surprised at how risky of a business this is, but there are lots of people who don't want my invention to ever reach the road. I have a hard time buying parts for my car for obvious reasons. I've been blacklisted in many areas," says the 79-year-old retired construction engineer and former mechanic.

Starbard says he first invented the system back in the late 1930s, but the: his partner, his partner's wife, and the car with the system, mysteriously disappeared one day and for obvious reasons, he decided to abandon the idea.

"It got a little scary back then. My partner and his wife and the car were never discovered, so I decided to have no part of it."

Not until four years ago when he got the urge to rebuild and revise the system. Since his re-endeavor began, Starbard has invested nearly $150,000 into the system, much of which has been spent on the worldwide patents. In the car itself is nearly $40,000, he estimates.

Starbard's 1966 Impala has had two open showings. One in February in Sacramento where he took the car on a small demonstration run and the other at Mr. Ed's in Vacaville a few months back.

"I really hadn't intended to show the car at those times because all the patents hadn't come in, but I wanted to get reactions from people. Everyone is just amazed at the system and most agree that it's the system of the future."

Starbard plans on making a notorized test run in a few weeks in Vacaville. He wants the speed of the car to be notorized by a notary public, highway patrol officer and another witness.

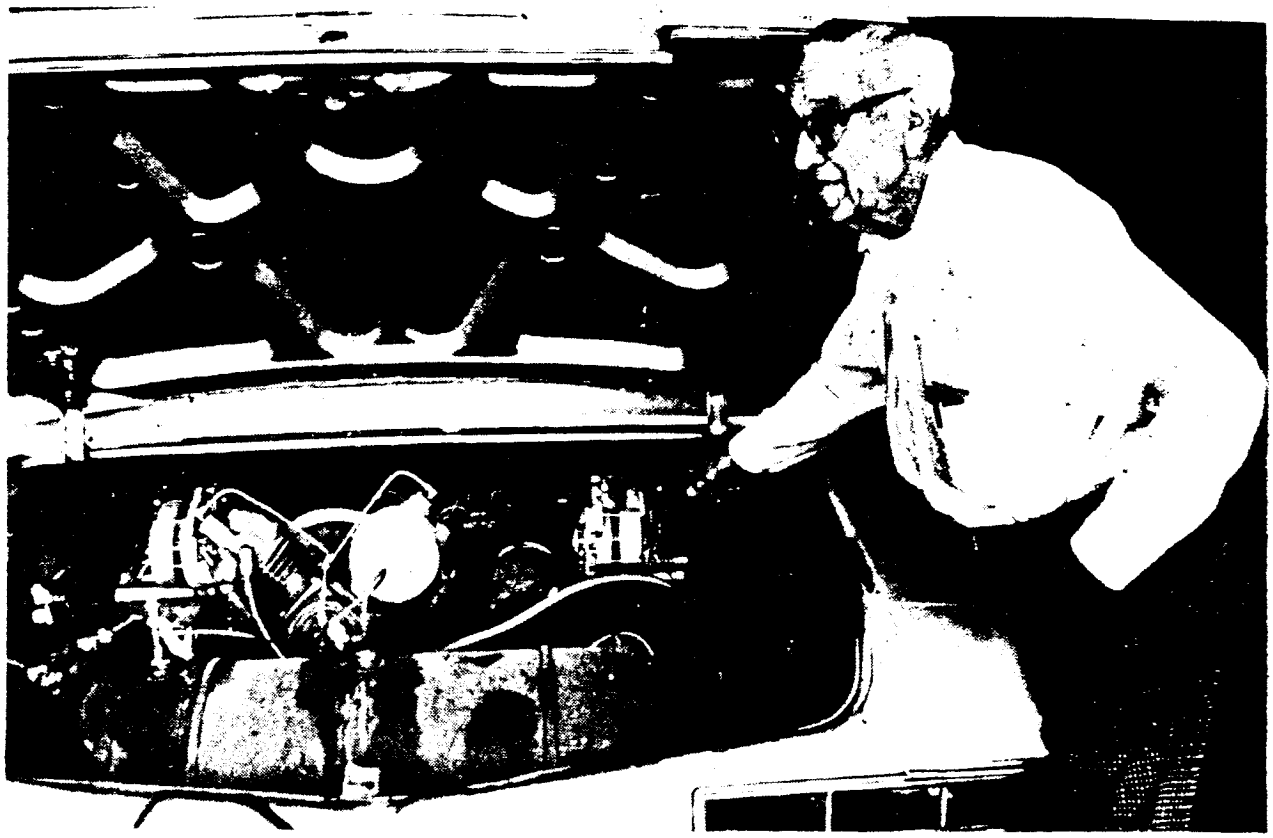
I've had the car up to 45 miles per hour and in a lighter frame it could probably do 75-80. It's so powerful it could probably climb a wall," added the inventor.

The horsepower of the car is unknown due to Starbard's keeping the car underwraps, but that's something he'll figure out when he makes the test run locally. He took the vehicle out for a drive in English Hills recently, its furthest test on the road, and says the car had no difficulty on the hills.

"I tell you, it's the car of the future. If it isn't, it'll be the shock absorbers that enable electric cars to obtain continued movement. And it's really simple."

The car runs on air supplied from air compressors that are run by small (golf cart) motors that get their source from six 12-volt batteries. The batteries are charged by two alternators that are activated by the newly designed shock absorbers. The air motors are charged by the air stored in the air tank (in the trunk) and are connected to the drive shaft on the transmission which inturn relays the motion to the rear wheels, resulting in movement.

The six batteries generate three horsepower each, which is multiplied 26 times by the shock absorbers' power, resulting in an abundance of power, points out Starbard.



The Air Machine

TRUNK ACCESSORIES — Ray Starbard shows off his well used trunk, filled with air compressors, batteries and a large air tank. He's pointing to one of the all important shock absorbers (see related story for details).

While putting his car together over the years, Starbard ran into certain problems, as all inventors do, many of which are minute, but nevertheless bothersome. However, one obstacle he ran into that totally threw him was the fact that the Department of Motor Vehicles made him get a smog device for his car.

"Imagine that, a smog device for an air car. That was absurd," says Starbard, who admittedly had problems finding a mechanic who would give him approval. "Most of them hadn't the slightest idea about the system and didn't know how to react."

The car is licensed and registered.

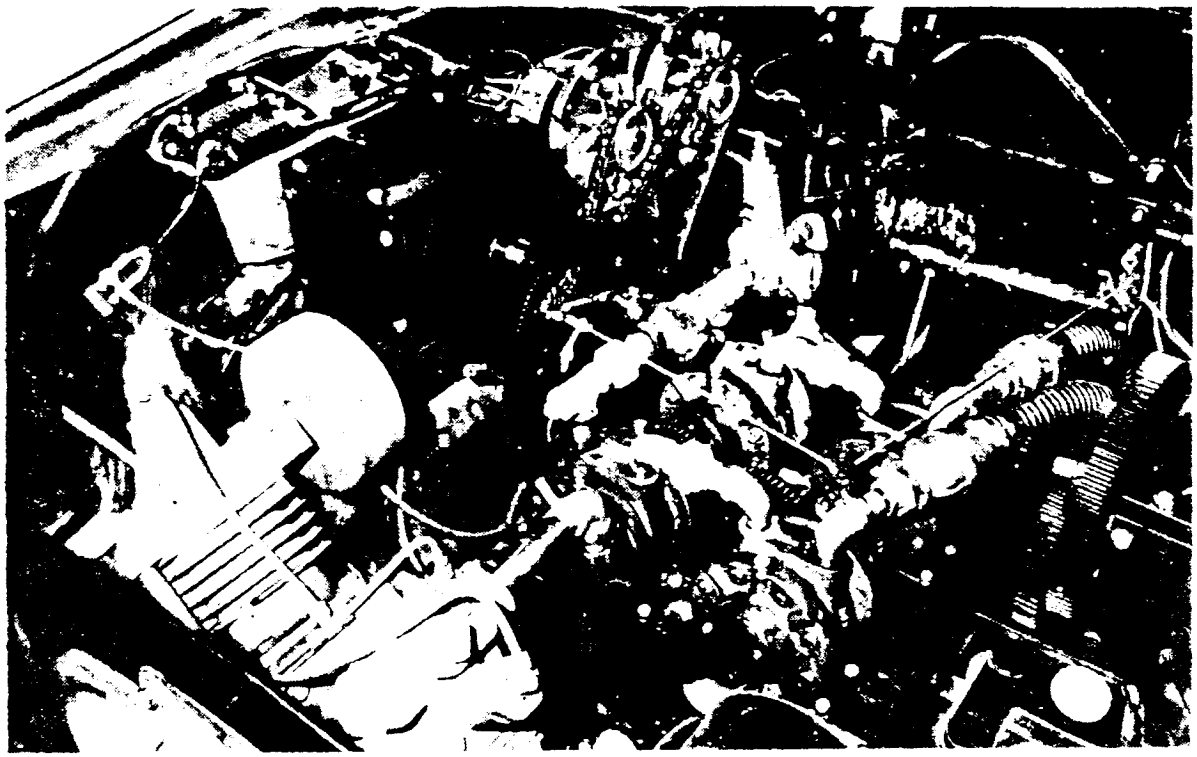
One might expect a 'wooshing' sound from an air-powered car, but instead Starbard's car gives off a slightly high pitched sound, which when unmuffled sounds like a jet taking off. With the mufflers, however, his Impala is the quietest thing on the street, next to a bicycle that is.

Starbard's system has drawn great interest across the county — "through the grapevine" — and he claims to receive thousands of dollars each week from people "who want to invest. But I'm not selling stock."

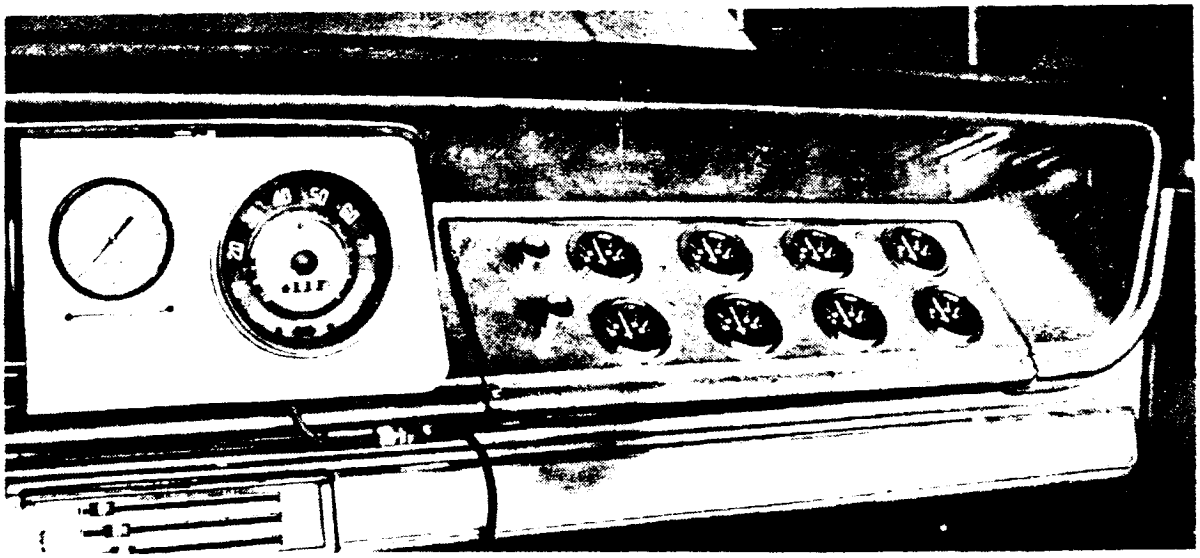
The system has received great interest from car manufacturers also, one of the reasons Starbard is so cautious in displaying the car and one of the reasons he feels threatened much of the time.

As for offers, he claims to have over 20 and a price tag running "high into the millions," but he's waiting until the U.S. patent is finalized before he sells.

Starbard feels he has invented the power system of the future, a system that will greatly change the automotive face of the world, and amazingly as it sounds he plans to use his earnings to greatly change the face of the world in another way. And all because of Mother Nature's purest gift — Air.



AIR ENGINE — Ray Starbard's air-powered engine in its 'simplest' form. The car uses no gas, oil or water and rarely runs out of 'air.' (Reporter Photos by Trey Weir).



AIR-POWERED DASH — The dashboard of Ray Starbard's airpowered car is covered with altimeters (air-pressure gauges) and a new odometer to keep account of actual 'air-traveled' miles.

'It's the Car of the Future . . .'

United States Patent [19]

Starbard

[11] **3,981,204**

[45] **Sept. 21, 1976**

[54] **SHOCK ABSORBER DRIVE UNIT**

[76] Inventor: **Raymond E. Starbard**, 929 Drever St., West Sacramento, Calif. 95691

[22] Filed: **Jan. 6, 1975**

[21] Appl. No.: **539,028**

[52] **U.S. Cl.** **74/34**; 320/61

[51] **Int. Cl.²** **F16H 21/52**

[58] **Field of Search** 74/34; 320/61

[56] **References Cited**

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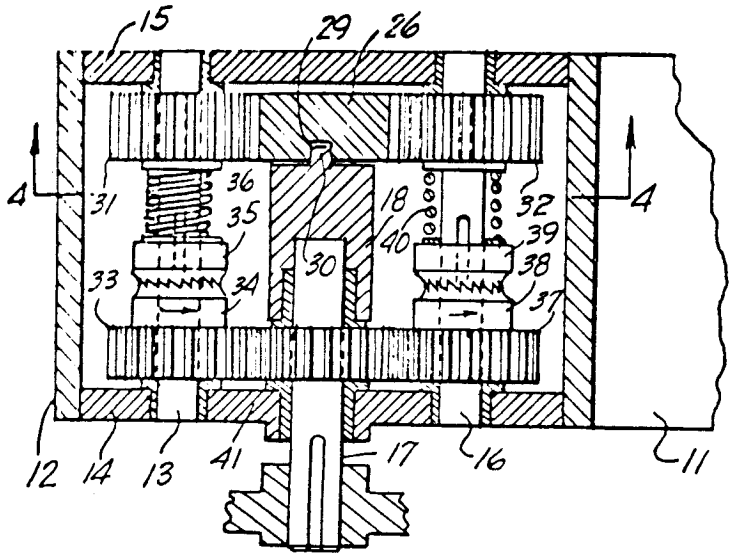
Primary Examiner—Benjamin W. Wyche
Assistant Examiner—Wesley S. Ratliff, Jr.
Attorney, Agent, or Firm—Blair & Brown

[57] **ABSTRACT**

A shock absorber drive unit for motor vehicles which translates the vertical reciprocating motion of the under carriage of a motor vehicle to one-way rotary motion through a rack and drive gears connected through one-way clutches to a gear train. Alternators driven by belts from the gear train provide sufficient drag to produce a shock absorbing action for the unit while simultaneously producing electricity for charging batteries or other uses.

1 Claim, 5 Drawing Figures



U.S. Patent Sept. 21, 1976 Sheet 1 of 2 3,981,204

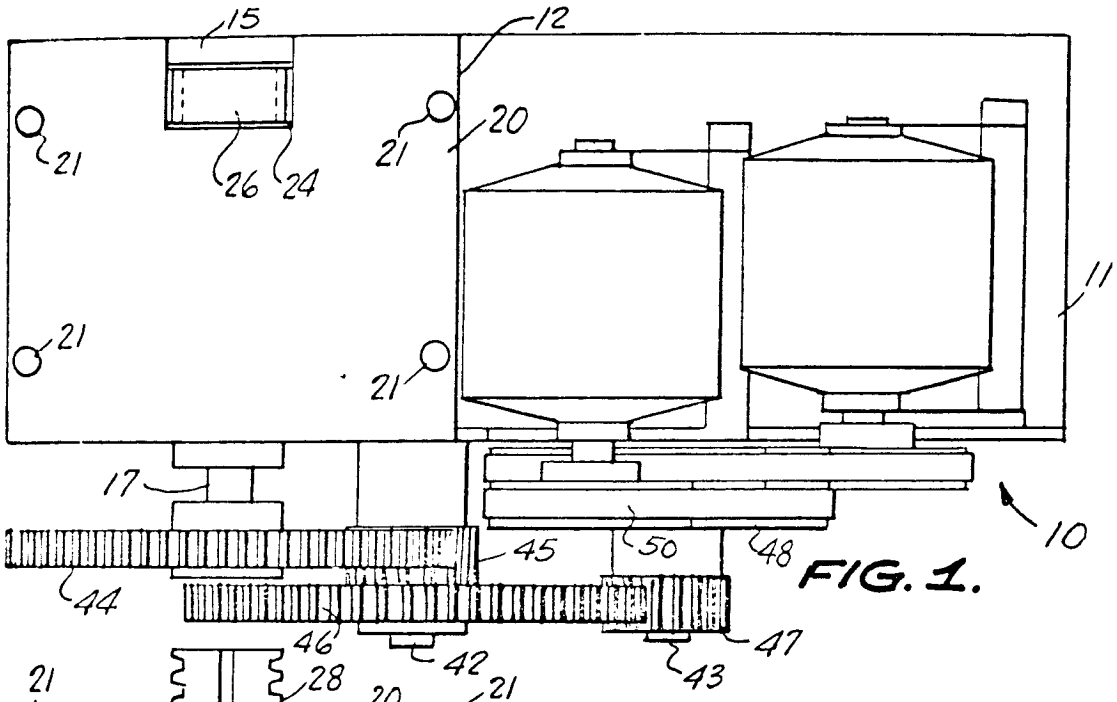


FIG. 1.

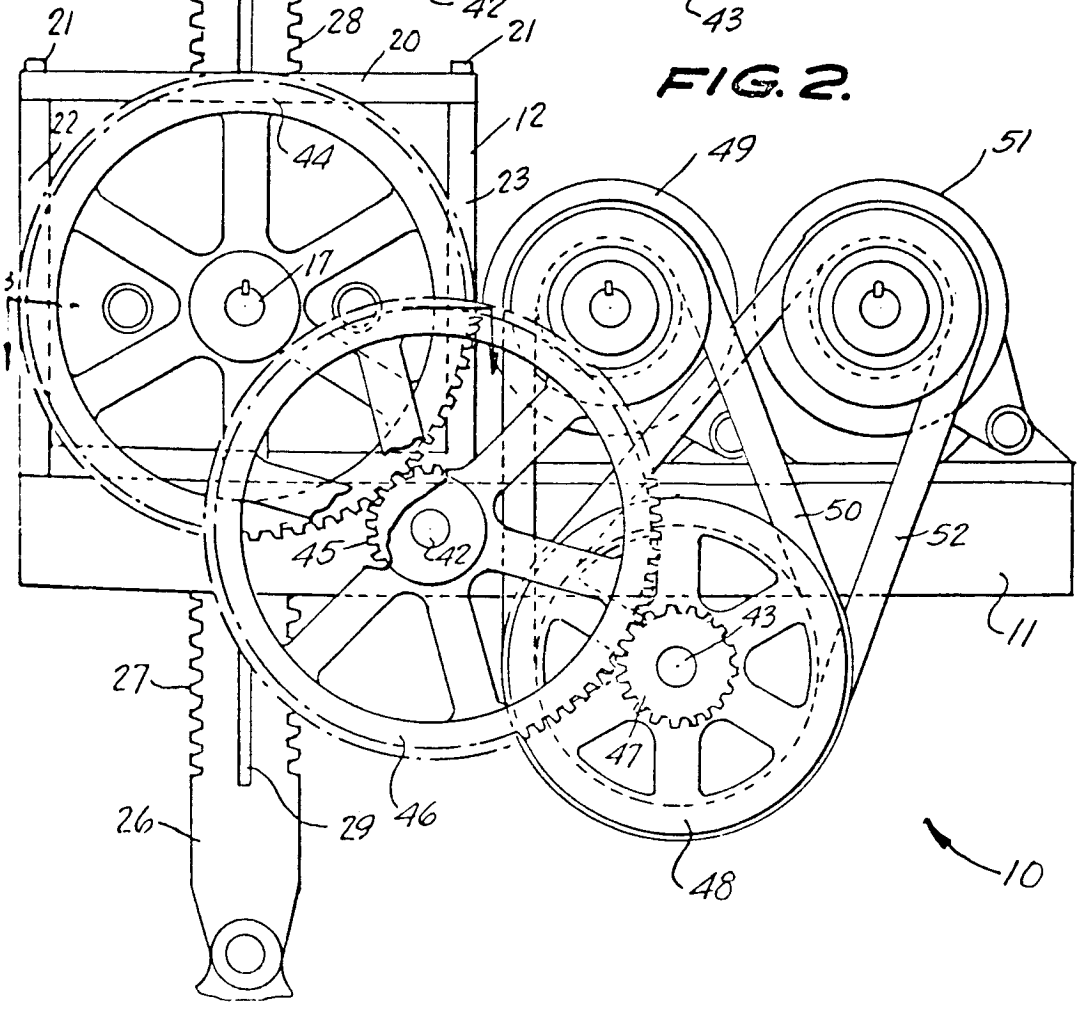


FIG. 2.

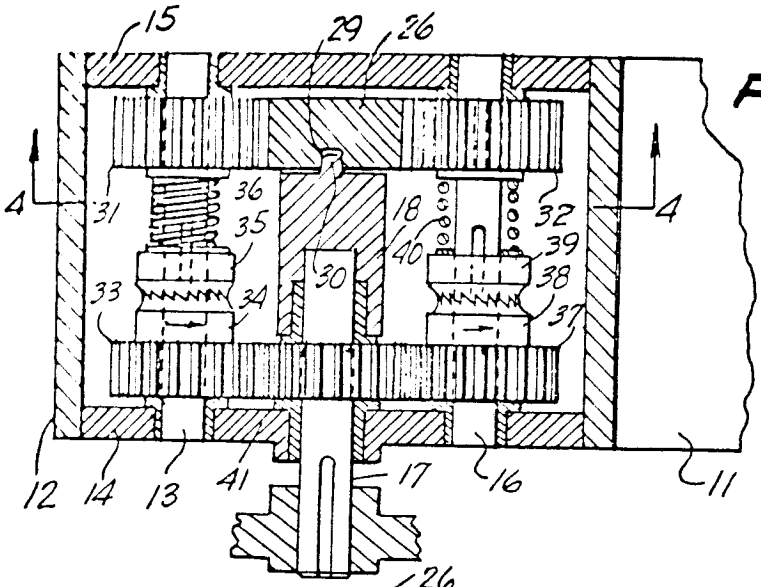


FIG. 3.

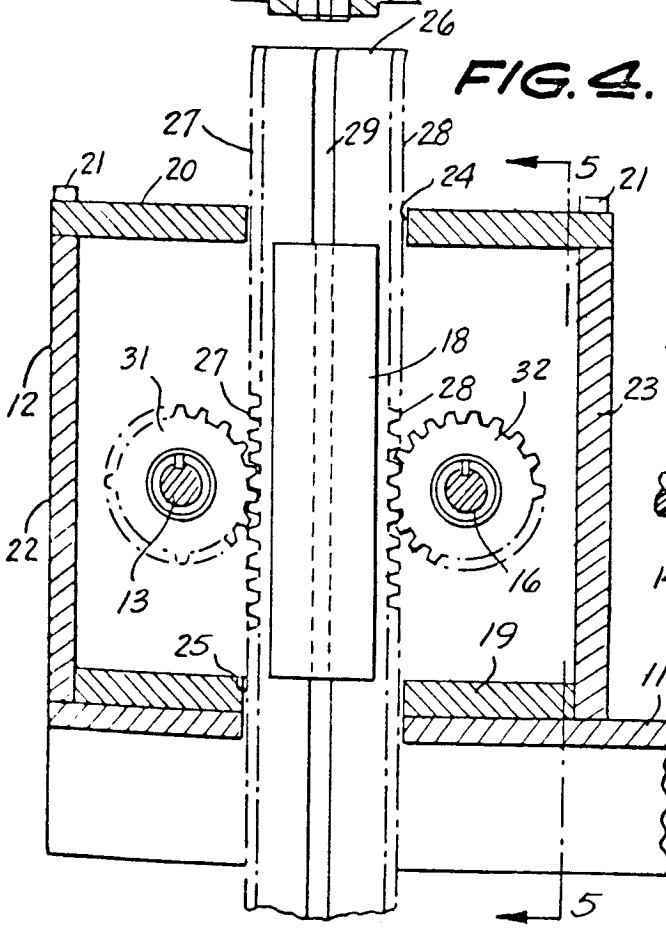


FIG. 4.

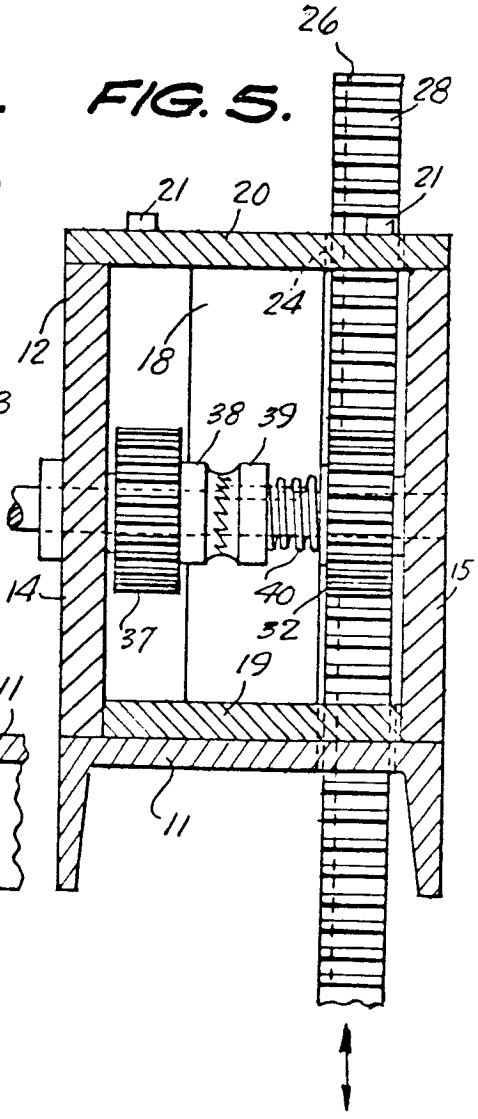


FIG. 5.

SHOCK ABSORBER DRIVE UNIT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to shock absorbers which produce useful power in a motor vehicle.

SUMMARY OF THE INVENTION

In the shock absorber unit of the instant invention a bar having rack teeth on opposite sides thereof is provided for vertical reciprocation in a motor vehicle and attached to the running gear so as to be vertically reciprocated thereby during the operation of the motor vehicle. Gears are meshed with rack teeth on opposite sides of the rack bar so as to be rotated as the rack bar reciprocates. The gears are connected through oppositely arranged one-way clutches so as to alternately drive a single gear in one direction only. The single gear is connected through a gear train and belts to alternators which provide sufficient drag on the system to produce a shock absorbing effect for the unit while simultaneously producing electricity for charging batteries or other uses.

The primary object of the invention is to provide power producing shock absorbers for a motor vehicle.

Other objects and advantages will become apparent in the following specification when considered in light of the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of the invention;

FIG. 2 is a side elevation of the invention shown partially broken away for convenience of illustration;

FIG. 3 is a fragmentary horizontal sectional view taken along the line 3—3 of FIG. 2, looking in the direction of the arrows;

FIG. 4 is a fragmentary vertical sectional view taken along the line 4—4 of FIG. 3, looking in the direction of the arrows; and

FIG. 5 is a fragmentary transverse vertical sectional view taken along the line 5—5 of FIG. 4, looking in the direction of the arrows.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail, wherein like reference characters indicate like parts throughout the several figures, the reference numeral 10 indicates generally a shock absorber unit for motor vehicles constructed in accordance with the invention.

The shock absorber unit 10 includes a channel shaped base member 11 which is adapted to be secured to the frame of a motor vehicle in any desired manner. A generally rectangular housing 12 is secured to the base member 11 and extends upwardly therefrom. A shaft 13 is journalled in the front wall 14 of the housing 12 at one end and in the rear wall 15 at its opposite end. A shaft 16 is arranged parallel to the shaft 13 and is similarly journalled in the front wall 14 and rear wall 15. A shaft 17 is journalled in the front wall 14 and in a block 18 secured to the bottom wall 19 of the housing 12. The housing 12 has a top wall 20 secured by studs 21 to the side walls 22, 23 of the housing 12. A rectangular opening 24 extends through the top wall 21 adjacent the rear wall 15 and a rectangular opening 25 extends through the bottom wall 19 and the channel 11 adjacent the rear wall 15 in aligned relation to the opening 24.

A generally rectangular rack bar 26 having rack teeth 27 on one side thereof and rack teeth 28 on the opposite side thereof, is mounted for vertical reciprocation through the openings 24, 25 as can be clearly seen in FIGS. 3 and 4. An upright slot 29 is formed in the forward face of the rack bar 26 and engages over a tongue 30 on the block 18 in the housing 12.

A gear 31 is keyed for the shaft 13 and meshes with the rack teeth 27 on the bar 26. A second gear 32 is keyed to the shaft 16 and meshes with the rack teeth 28 of the bar 26. A gear 33 is journalled on the shaft 13 and is secured to one-way clutch element 34 also journalled on the shaft 13. A second oneway clutch element 35 is keyed to the shaft 13 and is held in engagement with the one-way clutch element 34 by means of a coil spring 36 encompassing the shaft 13 and extending between the gear 31 and the one-way clutch element 35.

A gear 37 is journalled on the shaft 16 and is rigidly secured to a one-way clutch element 38 also journalled on the shaft 16. A one-way clutch element 39 is keyed to the shaft 16 and is held in engagement with the one-way clutch element 38 by means of a coil spring 40 encompassing the shaft 16 and extending between the gear 32 and the one-way clutch element 39. The one-way clutch elements 35, 39 are mounted for endwise sliding movement on the shafts 13, 16 respectively.

A gear 41 is secured to the shaft 17 intermediate the gears 33, 37 and meshing with the gears 33, 37 to be driven thereby. A shaft 42 is rigidly mounted to the base member 11 and a second shaft 43 is also rigidly mounted to the base 11 in parallel relation to the shafts 42 and 17. A relatively large spur gear 44 is fixed to the shaft 17 and meshes with a relatively small spur gear 45 journalled on the shaft 42 and rigidly secured to a relatively large spur gear 46. A relatively small spur gear 47 is journalled on the shaft 43 and meshes with the spur gear 46. A double V-pulley 48 is fixed to the spur gear 47 to revolve therewith.

An alternator 49 is mounted on the base member 11 and is driven by a belt 50 extending from the double V-pulley 48. A second alternator 51 is mounted on the base member 11 and is driven by a V-belt 52 extending from the double V-pulley 48.

In the use and operation of the invention the unit 10 is secured to the frame of a motor vehicle in any desired manner with the lower end of the rack bar 26 connected to vertically moveable portions of the running gear in the manner of connecting conventional shock absorbers. As the motor vehicle moves over the earths surface the running gear vertically reciprocates and thus causes the rack bar to reciprocate with respect to the housing 12. As the rack bar reciprocates the rack teeth 27 rotate the spur gear 21 and the rack teeth 28 rotate the spur gear 32. As the rack bar moves downwardly with respect to the housing 12, the gear 31 as seen in FIG. 4 rotates in a clockwise direction to thus rotate the one-way clutch element 35 in a clockwise direction driving the one-way clutch element 34 and the gear 33 in a clockwise direction so as to turn the shaft 17 in a counter clockwise direction. As the rack bar 26 reverses its direction and moves upwardly with respect to the housing 12. The one-way clutch elements 34, 35 slip by each other so that no drive occurs to the gear 33. The gear 32 is then rotated in a clockwise direction and through the one-way clutch elements 38,

39 rotates the gear 37 in a clockwise direction to thus rotate the shaft 17 in a counter clockwise direction. The one-way elements 38, 39 slip by each other when the gear 32 is rotated in a counter clockwise direction during downward movement of the rack bar 26 with respect to the housing 12.

The shaft 17 is thus rotated solely in a counter clockwise direction by alternate driving connections to opposite sides of the rack bar 26. The gears 44, 45, 46 and 47 provide a relatively high speed drive for the alternators 49, 51. The driving of the alternators 49, 51 produces a drag on the movement of the rack bar 26 sufficient so that the rack bar 26 has a shock absorbing effect on movements of the running gear of the motor vehicle on which the unit 10 is mounted.

Having thus described the preferred embodiment of the invention it should be understood that numerous structural modifications and adaptations may be resorted to without departing from the spirit of the invention.

What is claimed is:

1. A shock absorber power system for motor vehicles of the type supported on four wheels and including a

frame comprising a plurality of units secured to the frame adjacent each wheel of the motor vehicle with each of said units including a housing, a rack bar mounted for vertical sliding movement vertically through said housing, said rack bar having rack teeth formed on diametrically opposed sides thereof, means in said housing guiding said rack bar in its vertical reciprocation, a pair of parallel shafts journalled in said housing on opposite sides of said rack bar, a gear secured to each of said shafts and meshing with the rack teeth on opposite sides of said rack bar, a one-way clutch mounted on each of said shafts, a spur gear mounted for rotation on each of said shafts rotatably driven by one of said one-way clutches, a third shaft journalled in said housing and extending outwardly therefrom, a spur gear secured to said third shaft and meshing with the gears on said parallel shafts, a base supporting said housing, a gear train mounted on said last named shaft and said base, a pair of electric alternators secured to said base, and means extending from said gear train for rotating said alternators to produce electricity.

* * * * *

Mr. Starbard is deceased. Our correspondent who met him says the car was very complicated, involving too many conversions of energy. Starbard admitted that he could only get the car up to 30 mph on a level road. It's rumored that someone used the Starbard name and reputation in air car design to con the public, though it wasn't Starbard himself.

Prototypes are usually built to prove an idea rather than to display the maximum achievable results from that idea. If it's true that this car had to be recharged quite seldom, as Starbard claimed in the newspaper article, then his claims should be looked at, and the speed the car is able to go should bear less weight in judging the invention on its own merits.

Neutralizing Wind Resistance

To overcome wind resistance, some suggest installing aerodynamic air channels to direct the wind into turbines which run compressors or generators. This design will not consider generators, since conversion from air to electricity and back to air is unnecessarily wasteful and complicated. The experience of watching and listening to windmills operate suggests that they are too noisy and vibrate too much to be used on cars to recover the 10 to 20 horsepower used to plough air at 60 mph. A ten horsepower wind turbine isn't something you can bolt on top of a car; it would rattle the car to pieces. Windmills are made to turn themselves away from the wind during 60 mph winds, to avoid self-destruction.

The first step in eliminating wind resistance is to build a car body with the best possible aerodynamically efficient shape. The second step is unique in that the wind turbine idea criticised above can survive in spirit using a means of recovering losses due to wind resistance, with no moving parts.

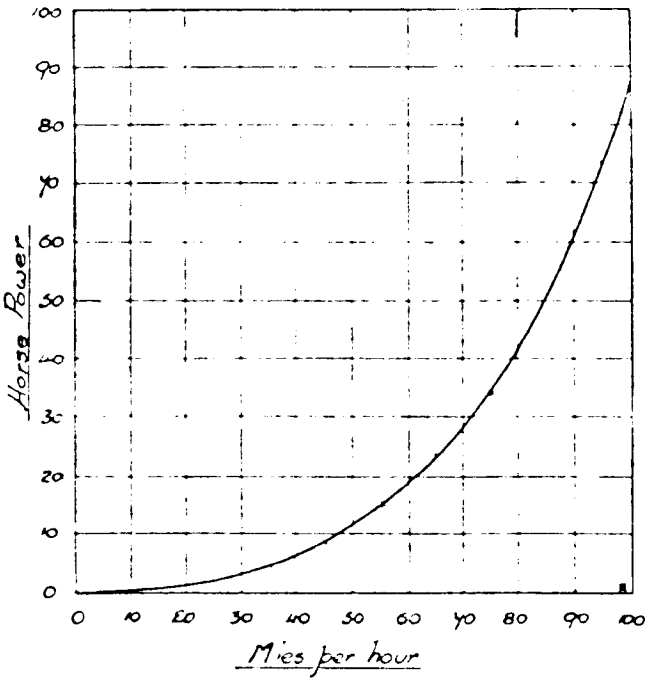
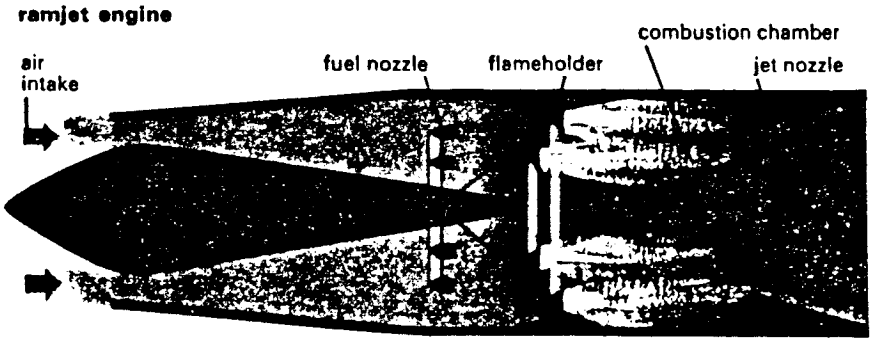


Chart for determining horsepower required to overcome wind resistance at various speeds, based on a cross-sectional area of 12 square feet; if the car had a frontal area of 6 square feet, horsepower requirement would be half what the chart shows; chart taken from The Motor Car, by Duncan Mc Millan, 1915, Longmans, Green & Co., London

The air that the car pushes into slows the car down because the car is a wall that blocks the air's flow. The air that the car leaves behind slows the car down because the just-removed presence of the car had displaced air which is still partially absent. Thus the air pressure just behind the car is less than that of the atmosphere in general so it sucks the car backwards. Since the car being a wall blocking air flow is the problem, is there a way to remove the wall without removing the car?

Most of the air parted and pushed up over the car can be directed into air tunnels at the back of the car's roof which direct the air through nozzles into the space behind the car. The advantage of this relocation of pushed-aside air is twofold. First, the energy added to the air when the car pushes it aside becomes reusable as kinetic energy because of the shape of the nozzles that direct it to the suction space behind the car. The jet engine or

impulse engine uses the same principle as its motive power. Unlike the heat engine, which converts potential energy in the form of heat and pressure directly into work in the engine, the jet engine converts the energy in its fuel medium's motion, its kinetic energy, into an equal and opposite reaction that impels the vehicle forward. Therefore jets can power vehicles in space, in a vacuum. So the jet impulse effect seems like a fitting regeneration process to situate in a partial vacuum like the one right behind the car. The second reason that proper placement of the air nozzles can help neutralize wind resistance is that the air displaced when the car wedges into it can be strategically put right back where it came from instead of waiting for it to turbulently find its way there. The wind nozzles should eliminate much of the suction cavity behind the car.



How Things Work
by Michael Pollard
Larousse & Co, NY '78

One more air drag that can be eliminated is the suction intake on the compressor of the air car. Part of the wind relative to the car's motion can be directed into a tunnel feeding the compressor's intake valve so the compressor has no work to do in sucking its air in. The quantity of air needed to keep up with the compressor's intake needs is many times less than what's easily available. The amount of air pushed aside by the car is abundant to the point of redundancy; most of the wind will be sent to replenish the suction cavity behind the car, instead of into the compressor. A diverging nozzle, or pipe with an increasing diameter, will be placed at the tip of the car. Like the intake nozzle on the ramjet engine, it will take in a small part of the oncoming air and convert a small part of its kinetic energy into potential energy, or pressure. This captured energy will eliminate suction drag into the compressor.

Because the jet nozzles at the back and the ram compressor at the front have no moving parts, they can be considered quite efficient. Their effectiveness will be increased to the maximum limit by taking into the redirection tunnels the maximum possible proportion of the air that the front of the car displaces. The intake tunnels at the back of the car can be made of fiberglass.

With this technique, the wind resistance of any car of aerodynamically superior shape can be almost completely neutralized.

Gas Turbine Aerothermodynamics, Sir Frank Whittle
Pergamon Press, 1981

'Ram' Compression and Intake Design

Except at take off and low subsonic speeds, for reasons which will be given below, the efficiency of ram compression is very high at moderate and high subsonic speeds if the axis of the intake differs little from the line of flight, i.e., in the absence of yaw or other aerodynamic deflection of the air at intake entry, and there is no error of significance in assuming that the efficiency of ram compression is 100%.

READER'S DIGEST *May* *1987*

THEY CREATED THE JET AGE

BY NOEL VIETMEYER

The drama began in 1929 when 22-year-old Frank Whittle, an officer in Great Britain's Royal Air Force (R.A.F.), proposed a new form of propulsion that would enable planes to fly very high and very fast. The secret: eliminate propellers and piston engines because above 20,000 feet the air is too thin for propellers to "bite" efficiently and for piston engines to "breathe."

Almost no one took Whittle seriously. A plane without propellers? Unthinkable. Whittle's cigar-shaped device stuffed air into itself with a fan that acted like a windmill. The compressed air was heated by burning fuel, and the vast volumes of resulting exhaust gases were ejected with such velocity that the counter-reaction would force a plane forward. The British Air Ministry's principal adviser on engine matters checked Whittle's calculations and dismissed the whole concept.

One person had faith, however: an instructor named Johnson at Whittle's R.A.F. base. On January 16, 1930—almost ten years before World War II broke out—he had Whittle submit his idea to the British Patent Office. Whittle and Johnson tried over the next two years to interest private industry. There were no takers. The idea of the jet lay neglected.

IN 1948, the British government finally publicly recognized Whittle's contribution. It awarded him a cash payment of £100,000 ($400,000), and King George VI knighted him. Since then, countries, cities, universities and professional societies from all over the world have showered him with medals, awards and honorary degrees. In 1976 he immigrated to the United States, teaching at the U.S. Naval Academy at Annapolis and living quietly out of the public spotlight. Today his home is in rural Maryland.

Jet Aircraft Power Systems by Jack V. Casamassa
Copyright 1965, McGraw-Hill Book Company
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THE RAMJET

The word "athodyd" is derived from the words "AeroTHermODYnamic Duct."

Briefly, the athodyds differ from the gas-turbine group in that the turbine wheel and compressor assembly are omitted. In the case of the **ramjet** engine, compression is supplied merely by ram pressure as the engine is moved forward at a very high velocity. In the **pulsejet,** air intake is obtained by reducing the pressure in the combustion chamber momentarily to induce a fresh charge of fuel-air mixture to enter the combustion chamber.

By converting the kinetic energy of the incoming air into pressure, the ramjet is able to operate without a mechanical compressor. Therefore, the engine requires no moving parts and is mechanically the simplest type of jet engine which has been devised.

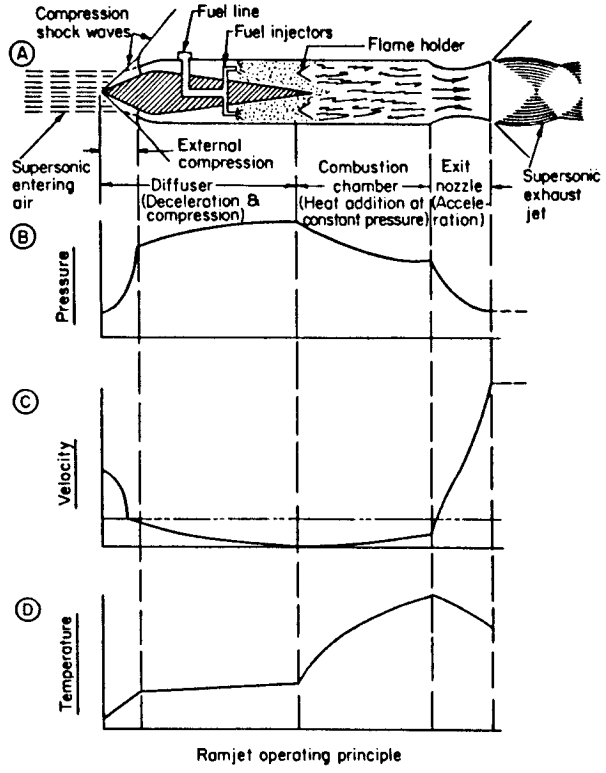


Figure 5·3 Operating conditions within a supersonic ramjet.

E. L. FITZ GIBBON.

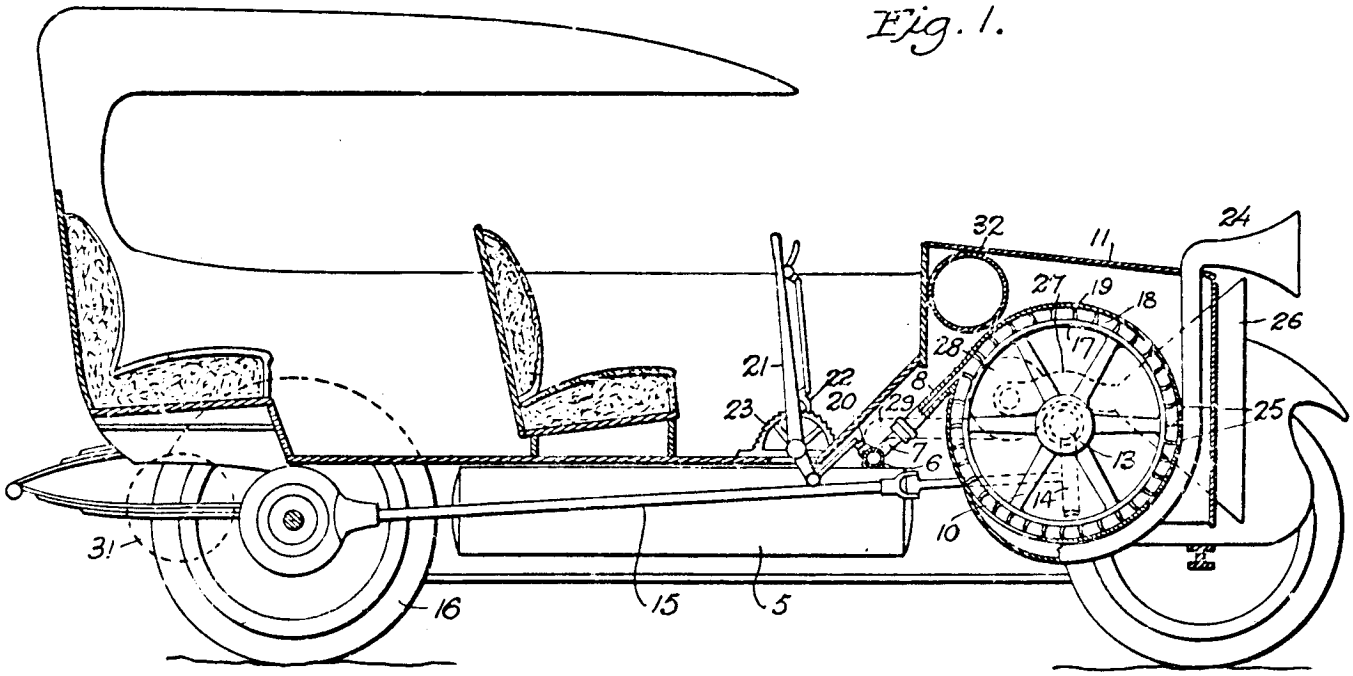
MOTOR VEHICLE.

APPLICATION FILED NOV. 29, 1919.

1,394,076. Patented Oct. 18, 1921.

2 SHEETS—SHEET 1.

Fig. 1.



Inventor:
Edward L. Fitz Gibbon,
by James F. Duhamel
Attorney.

E. L. FITZ GIBBON.

MOTOR VEHICLE.

APPLICATION FILED NOV. 29, 1919.

1,394,076.

Patented Oct. 18, 1921.

2 SHEETS—SHEET 2.

Fig. 2.

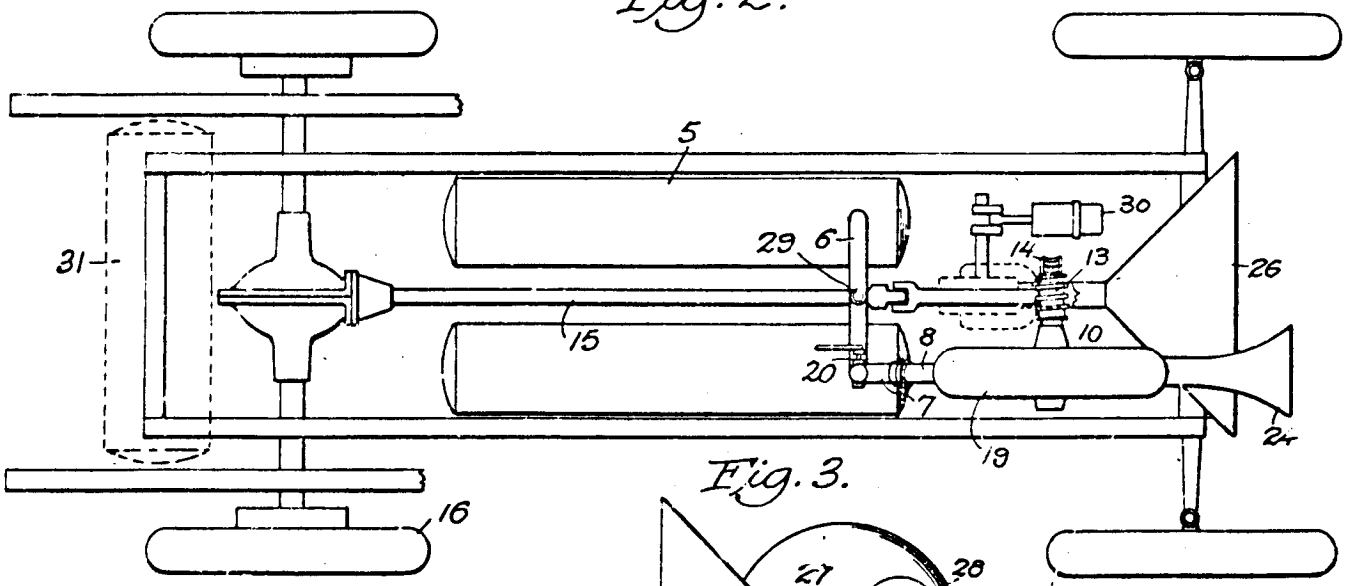
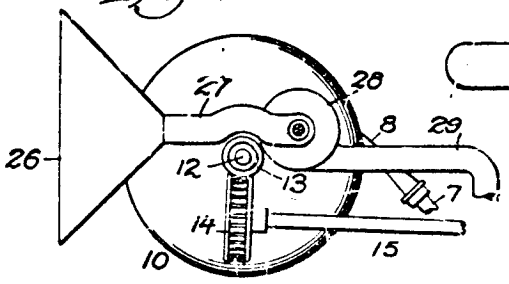


Fig. 3.



Inventor,
Edward L. Fitz Gibbon,
by James P. Duhamel
Attorney.

UNITED STATES PATENT OFFICE.

EDWARD L. FITZ GIBBON, OF BROOKLYN, NEW YORK.

MOTOR-VEHICLE.

1,394,076. Specification of Letters Patent. Patented Oct. 18, 1921.

Application filed November 29, 1919. Serial No. 341,530.

To all whom it may concern:

Be it known that I, EDWARD L. FITZ GIBBON, a citizen of the United States, and residing at Brooklyn, Kings county, New York, have invented certain new and useful Improvements in Motor-Vehicles, of which the following is a specification.

This invention relates to motor vehicles, and has for its object the driving of the same by compressed air and providing mechanical means therefor consisting of air tanks, a turbine motor, air intakes, and a compressor used in connection with one of the intakes to compress the air taken in at the same and supply it to the tanks for use in the motor. These and other details of the invention are more fully described in the following specification, set forth in the claims and illustrated in the accompanying drawings, wherein:

Figure 1, is a longitudinal sectional view of the improved vehicle.

Fig. 2, is a plan view of the chassis of the same.

Fig. 3, is a detail view of the reverse side of the motor and condenser.

In the use of compressed air for motor vehicles, considerable economy results from decrease in weight of fuel, eliminating the dangers of fire and explosion, intricate machinery, cost of fuel and other reasons. The initial cost of the motion power in the present invention is very moderate and comprises the tanks 5, adapted to be located within the running board and at a point very accessible for loading or unloading when a supply of air is needed. These tanks may be permanently located and the air supplied by means of a hose to a nipple. The two tanks 5, are connected by a pipe 6, and from the latter extends the pipe 7, carrying the nozzle 8, which is adapted to deliver a jet of air upon the blades 9, of the turbine wheel 10.

The wheel 10, is located, as motors generally are in this class of vehicles, at the front of the chassis and under the hood 11, and its shaft 12, carries a worm 13, to mesh with the wheel 14 of the driving shaft 15, that rotates the rear wheels 16, through the well known means.

The motor 10, consists of the ring 17, carrying on its outer edge a number of blades 18, adapted to rotate within the casing 19, at one side of which is the nozzle 7, to admit a blast of air from the air tanks to the periphery of the ring 17, and upon the blades 18 and through the pipes 6. In the latter, is the throttle valve 20, operated by the lever 21, adjacent the driver's seat and by means of which more or less air may be admitted to the turbine, the lever being adjustable by means of the pawl 22, and rack 23.

It is a well known fact that the air pressure on the front of a moving vehicle is sometimes considerable and means are shown in the drawings whereby resistance is eliminated and the pressure utilized. Above the hood and on line with the backs of the seats and the occupants, is a funnel 24, to collect the air which would have been exerted on those obstructions and neutralize it around the ring 17 and against the blades. After this volume of air and the compressed air are used against the blades the same is released and may be filtered out of the perforations 25, at the front side of the casing.

The hood itself is provided at its front side with a large funnel 26, covering the entire side and leading to the tube 27, which supplies the air thus collected at the front of the vehicle to the condenser 28, from which it is pumped through a pipe 29, to the tanks.

The condenser is operated by a small gas or other motor 30 and the same may operate a dynamo for lighting the vehicle, or storage batteries may be provided for a motor for the condenser and the lighting; or a steam engine may be provided.

Tanks 31 and 32, may be located at various parts of the vehicle where there may be empty spaces to carry the compressed air and be connected by suitable pipe with the tanks 5.

It is obvious that the device is equipped with the necessary valves, cocks, gages, etc., that are necessary to control the air and provide for the safety of the tanks, and that the parts may be otherwise arranged or modified without departing from the essential features above described and from the scope of the appended claims.

What I claim as new is:

1. In a motor vehicle, the combination of a vehicle, an intake funnel at the forward end of the frame, a turbine engine with rotating cups adapted to afford driving means for the wheels of the vehicle, a pipe from the intake funnel adapted to discharge air around the frame of the engine and into

the cups, and a container for compressed air to be supplied to the motor cups.

2. In a motor vehicle, the combination of a vehicle frame and wheels, an air driven turbine mounted in the frame and adapted to rotate the wheels, a circular casing inclosing the turbine, cups around the latter, compressed air driving means for the cups, a throttle valve operated from the seat of the vehicle, an air intake at the front of the vehicle, and a pipe from the intake to deliver air around the motor casing as an auxiliary to the compressed air driving means.

3. In a motor vehicle, the combination of a vehicle frame and wheels, a turbine motor adapted to drive the wheels, a circular casing inclosing the motor, compressed air driving means with a nozzle for the motor, an air intake at the front of the vehicle, and a pipe from the same to supply air to the motor around its under side.

In testimony whereof I have signed my name to this specification in the presence of a subscribing witness, this 25th day of November, 1919.

EDWARD L. FITZ GIBBON.

Witness:
A. W. BAKER.

United States Patent

[11] 3,556,239

[72] Inventor **Joseph W. Spaha**
5007 N. Kensington, Kansas City, Mo. 64119

[21] Appl. No. **761,560**
[22] Filed **Sept. 23, 1968**
[45] Patented **Jan. 19, 1971**

[54] **ELECTRICALLY DRIVEN VEHICLE**
4 Claims, 5 Drawing Figs.

[52] U.S. Cl. **180/68,**
290/4, 290/9, 290/44, 290/55
[51] Int. Cl. **B60l 11/14,**
B60d 9/00
[50] Field of Search 120/65;
290/4, 9, 19, 22, 55, 54, 44, 43; 105/63; 180/7, 60

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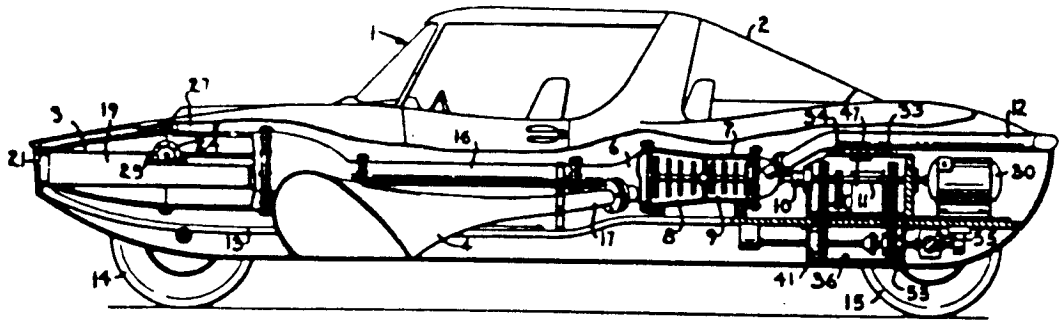
Primary Examiner—Benjamin Hersh
Assistant Examiner—Milton L. Smith
Attorney—Fishburn, Gold and Litman

ABSTRACT: A battery powered automobile includes an air operated turbine fed by front and side air scoops for providing both charging current to the batteries and driving power for the automobile. An auxiliary internal combustion engine is included for use when necessary. Deceleration and wind sensitive controls operate door structure on the front air scoop so that it opens, increasing drag, only under predetermined conditions. Braking energy is utilized to help charge the batteries.



PATENTED JAN 19 1971

3,559,239

SHEET 1 OF 2

Fig. 2.

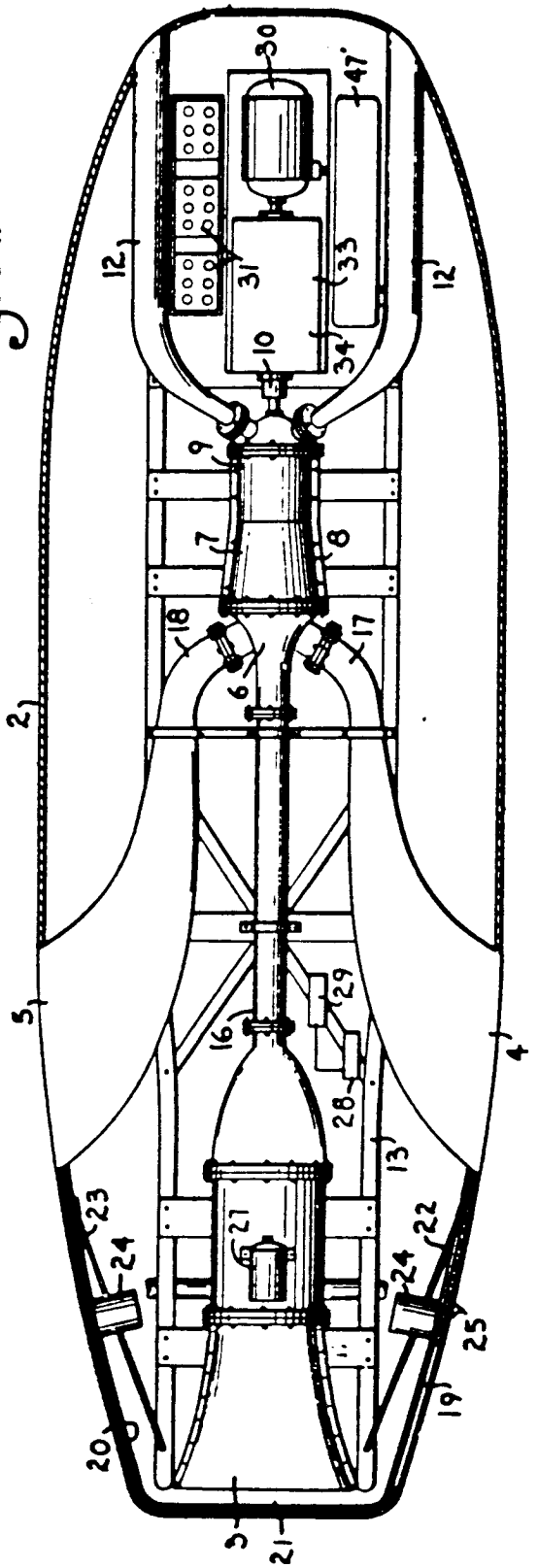
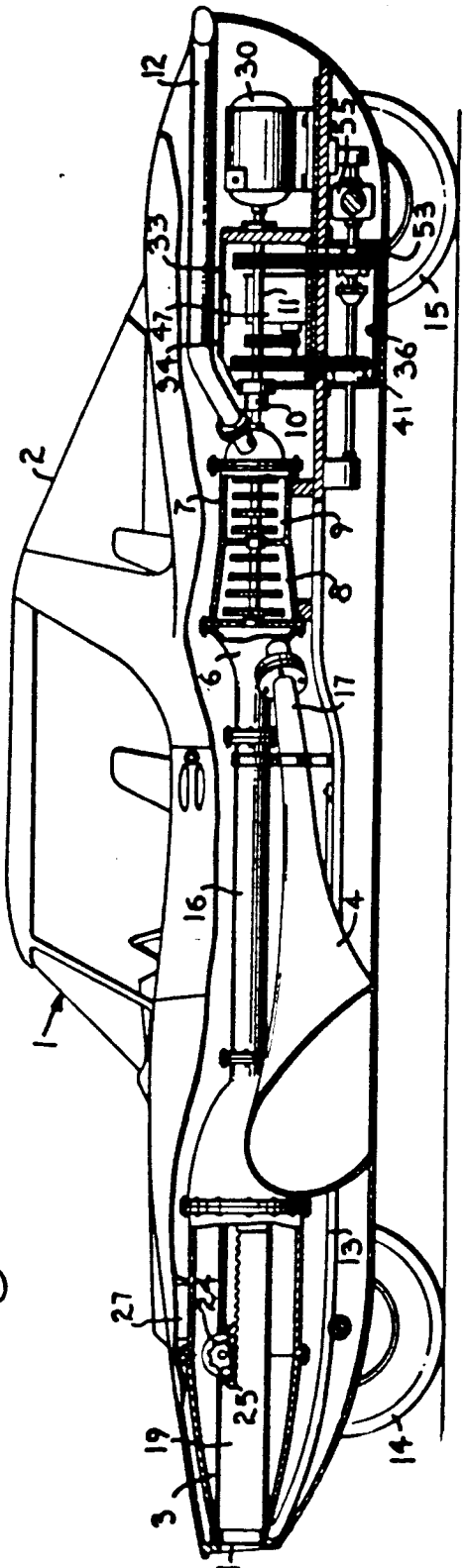


Fig. 1.



INVENTOR.
JOSEPH W. SPAHN

BY

Fishburn, Gold & Litvin

ATTORNEYS

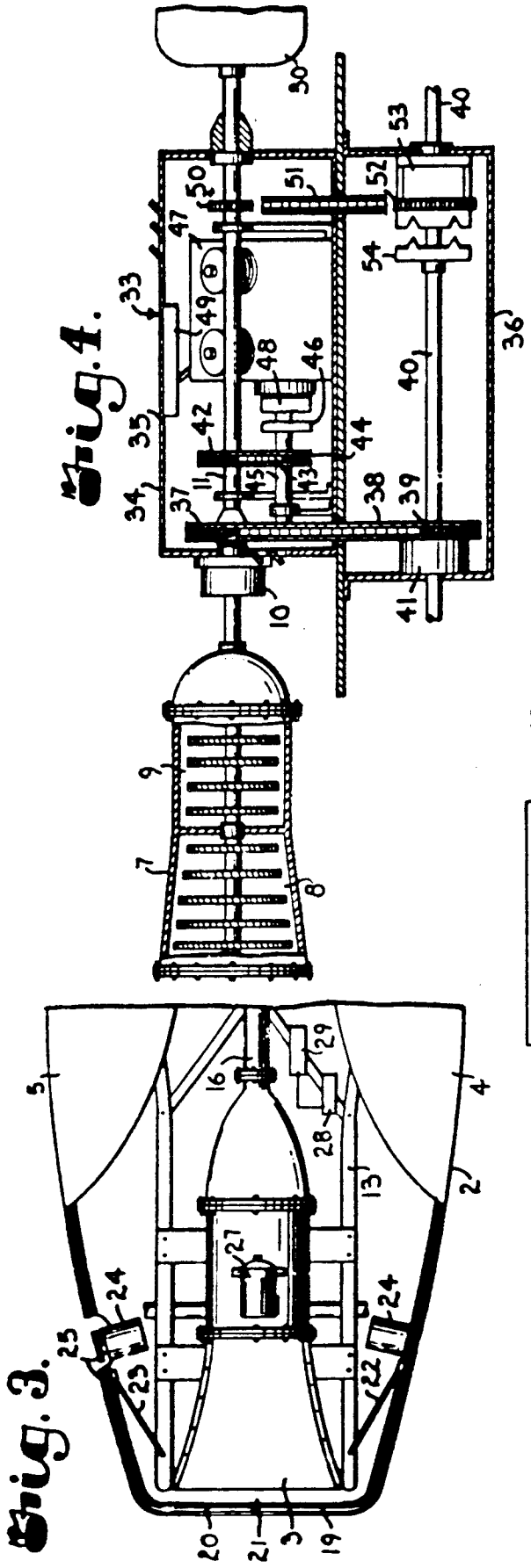


Fig. 3.

Fig. 4.

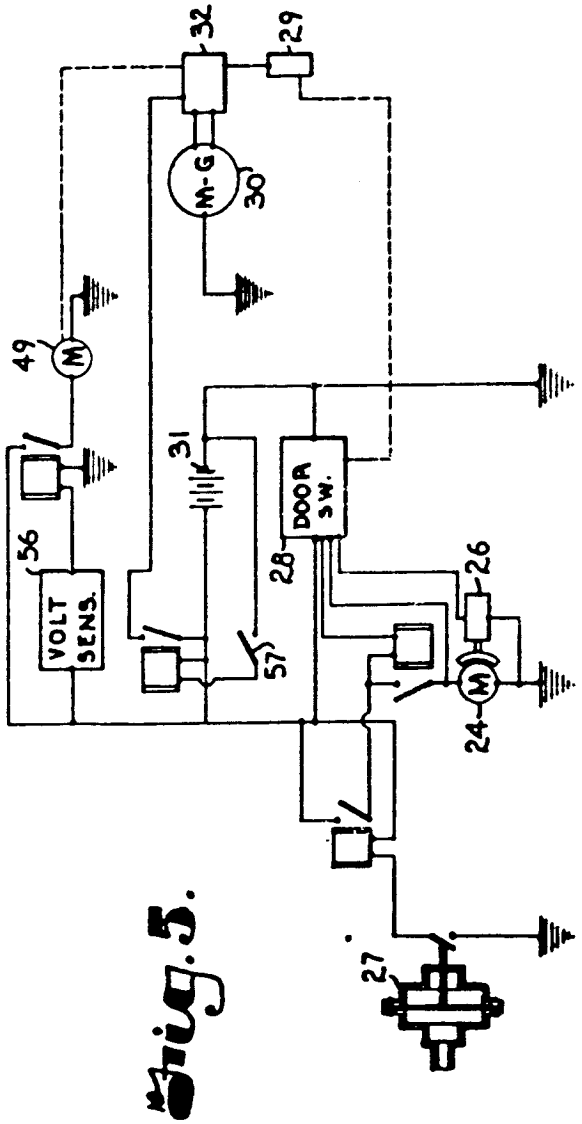


Fig. 5.

INVENTOR.
JOSEPH W. SPAHN

BY

Fishburn, Gold & Litman

ATTORNEYS

86

ELECTRICALLY DRIVEN VEHICLE

This invention relates to propulsion systems for a vehicle and more particularly to improvements in a battery driven automobile.

A vehicle constructed in accordance with this invention includes a source of portable electrical energy, such as batteries, feeding an electric motor connected through a suitable drive train to the wheels and of the type adapted to function as a generator when driven. An air turbine is mounted on the vehicle and receives relatively moving air for the purpose of recharging the battery. Thus, both braking energy and the energy of moving air are used for recharging the battery. An auxiliary internal combustion engine is provided to insure propulsion when sufficient electrical energy is not available.

The principal objects of the present invention are: to provide an electrically driven vehicle which utilizes multiple sources of energy for recharging batteries; to provide such a vehicle wherein energy is tapped to recharge the batteries only where such action will not interfere with desired propulsion of the vehicle; to provide such an arrangement wherein wind energy for recharging batteries is obtained both from forwardly directed and laterally directed scoops so that crosswind energy as well as normal air flow may be utilized; and to provide such an arrangement wherein braking energy is used for creating charging current and an auxiliary power source in the form of an internal combustion engine is included for use when necessary.

Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings wherein are set forth by way of illustration and example certain embodiments of this invention.

FIG. 1 is a partially schematic side elevation of an automobile embodying this invention with portions broken away to show interior construction.

FIG. 2 is a partially schematic cross-sectional plan view showing interior construction of the automobile.

FIG. 3 is a fragmentary plan view similar to FIG. 2 but showing front air scoop doors in closed position.

FIG. 4 is a fragmentary cross-sectional side elevation on a larger scale showing the power train of the automobile.

FIG. 5 is a schematic wiring diagram of the vehicle electrical components.

Referring more in detail to the drawings.

The reference numeral 1 generally indicates an automobile constructed in accordance with this invention. The automobile 1 comprises a streamline body 2 designed for minimum resistance to movement through the atmosphere and having a front opening air scoop 3 and lateral air scoops 4 and 5 opening at the respective sides of the structure. The air scoops 3, 4, and 5 respectively communicate into a manifold 6 forming the mouth or input of an air turbine 7 of the type having a free wheeling, low pressure forward section 8, which compresses the air therein while directing it rearwardly into a higher pressure section 9 fixed on a common shaft with an overrunning clutch 10. The clutch 10 is drivingly engaged with a rearwardly directed shaft 11 when the rotational speed of the turbine section 9 tends to exceed that of the shaft 11.

The air in the higher pressure section 9, after being utilized, exhausts through rearwardly opening exhaust pipes 12 which are aided in evacuation when air flows over the body 2 due to the rear position thereon.

The body 2 is supported on a suitable frame 13 to which are rotatably journaled front wheels 14 and rear wheels 15 in the usual manner through conventional suspension structure (not shown). The scoops 3, 4, and 5, the ducts 16, 17, and 18 connecting the scoops to the manifold 6, and the turbine 7 are suitably mounted on the frame 13 along with the remaining propulsion structure described below.

Sliding flexible panels or doors 19 and 20 are engaged in suitable guides for meeting in the center of the mouth 21 of the scoop 3 to block entrance thereto. Elongated tension springs 22 and 23 urge the doors 19 and 20 to closed position

and motors 24 operating, in this example, through suitable rack and pinion sets 25 are adapted to selectively urge the doors open under predetermined conditions. The doors 19 and 20 are maintained in open position against the tension of the springs 22 and 23 by brakes 26 (FIG. 5) controlled by electrically operated means described below.

An air pressure or speed switch 27 is located on the body 2 in a position to sense the flow of air past the automobile and is operable to prevent the doors 19 and 20 from opening below a predetermined air speed. Functioning in conjunction with the switch 27 is a deceleration switch 28. The deceleration switch 28 is operable to actuate the motors 24 to open the doors 19 and 20 (assuming that sufficient air speed is sensed by the air pressure switch 27) when driving power is no longer applied to the automobile, as when the driver intends to slow his forward speed. The deceleration switch 28, for example, may be operated through suitable linkage with the automobile accelerator pedal 29. Through the functioning of the switches 27 and 28, the doors 19 and 20 are open only when there is sufficient air speed to efficiently operate the turbine 7 and the automobile does not require driving power. The closing of the doors 19 and 20 substantially streamlines the vehicle for minimum air resistance.

The lateral scoops 4 and 5, however, are always open to take advantage of any crosswinds which generally do not hinder the forward motion of the automobile.

Also mounted on the frame 13 is a motor 30 of the type which, when electrically energized, acts as a motor, but when driven, functions as a generator. A suitable bank of batteries 31 are carried on the frame 13 and electrically communicate with the motor 30 through a suitable conventional control 32 by which the desired torque and speed output of the motor is obtained when desired and current is directed into the batteries 31 when the motor is driven. The motor 30 is connected to the shaft 11 which forms part of a drive assembly 33 also mounted on the frame 13.

The drive assembly 33 comprises a housing 34 and, in this example, has an upper section 35 and a lower section 36. The upper section 35 contains a sprocket 37 fixed to the shaft 11 and mating with a chain 38 which in turn engages a sprocket 39 contained in the lower section 36 on a shaft 40. The sprocket 39 is rotatable with respect to the shaft 40 but forms the input to a fluid coupling 41, the output of which is fixed to the shaft 40. Thus, the rotation of the shaft 11 causes the rotation of the sprocket 39, but the latter rotation is not transferred to the shaft 40 until the torque output of the fluid coupling 41 overcomes the resistance of the shaft 40.

Also mounted on the shaft 11 is a sprocket 42 engaged with a chain 43 which, in turn, engages a sprocket 44 fixed to a shaft 45 which supports a clutch plate 46. An internal combustion engine 47 of suitable design is schematically shown within the housing section 35 and has the output thereof in the form of a clutch plate 48 adapted to be driven into engagement with the plate 46 through operation of an electrically actuated hydraulic actuator 49 noted below. A tank 47' for containing fuel is mounted on the frame 13 and connected to the engine 47.

An additional sprocket 50 is fixed to the shaft 11 and engages a chain 51 which engages a sprocket 52 mounted on a floating clutch 53 mounted on, but rotatable with respect to, the lower shaft 40. A clutch plate 54 is fixed to the shaft 40 and is adapted to be engaged by the floating clutch 53 when brake of the automobile is actuated in the usual manner. It is noted that the automobile brake also involves the usual wheel braking system (not shown). The shaft 40 projects rearwardly of the housing lower section 36 into a suitable gear box and differential system 55 wherein the desired drive ratios with the rear wheels 15 are obtained.

In operation, the automobile, through the control 32, is normally powered by the motor 30 receiving current from the batteries 31. If wind conditions are proper whereby the turbine 7, through the lateral scoops 4 and 5, produces an output speed at the clutch 10 which is greater than the rotational

speed of the shaft 11, the clutch 10 engages and the turbine 7 helps drive the automobile. During deceleration, the front scoop 3 is opened and the additional turbine intake helps drive the motor 30 for recharging the batteries. When electrical energy is required to drive the automobile but the batteries are discharged below a predetermined level, this condition is sensed by a suitable voltmeterlike device 56 which through a relay operates the actuator 49 which starts the internal combustion engine 47 and engages the clutch plates 46 and 48. The accelerator pedal 29 of the automobile is then operable to control the internal combustion engine 47 which continues to drive the automobile until the batteries are charged to a suitable energy level whereupon the device 56 causes deactuation of the engine and disengagement of the clutch plates 46 and 48.

When the automobile is decelerated, as by braking, the normal braking system of the car actuates the floating clutch 53 to engage the clutch plate 54 whereupon the rear wheels drive the shaft 40 which, in turn, drives the shaft 11 through the chain 51 but at a substantially higher ratio than usual, whereupon the energy of deceleration is utilized by the motor 30 to charge the batteries. If the braking force obtained through rotation of the motor 30 is insufficient, further depression of the brake pedal will operate conventional automobile brakes (not shown). Ignition switch 57 is provided for the usual purpose.

Although one form of this form of this invention has been illustrated and described, it is not to be limited thereto except insofar as such limitations are included in the following claims.

I claim:

1. An electrically driven vehicle comprising:

a. a mobile frame having wheels mounted thereon for rolling movement along the ground;

b. an electric motor on said frame and operably connected to said wheels for driving said vehicle;

c. a storage battery on said frame and connected to said motor for driving said motor;

d. an air powered turbine on said frame, an air scoop on said frame and connected with said turbine for driving said motor, means selectively mechanically connecting said air turbine to said motor;

e. an auxiliary internal combustion engine mounted on said frame,

f. voltage sensing means associated with said battery and operably connected between said engine and said wheels; and

g. said last named means being operable to start said engine and connect said engine to said wheels when said battery is discharged to a predetermined condition.

2. An electrically driven vehicle comprising:

a. a mobile frame having wheels mounted thereon for rolling movement along the ground;

b. an electric motor on said frame and operably connected to said wheels for driving said vehicle;

c. a storage battery on said frame and connected to said motor for driving said motor;

d. an air powered turbine on said frame, an air scoop on said frame and communicating with said turbine for driving said motor, means selectively mechanically connecting said air turbine to said motor;

e. said air scoop being forwardly directed, and including; and

f. doors adapted to block said air scoop to reduce air resistance when said motor is driving said vehicle, said doors including air speed sensing means adapted to maintain said doors closed below a predetermined air speed.

3. An electrically driven vehicle comprising:

a. a mobile frame having wheels mounted thereon for rolling movement along the ground;

b. an electric motor on said frame and operably connected to said wheels for driving said vehicle;

c. a storage battery on said frame and connected to said motor for driving said motor;

d. an air powered turbine on said frame, an air scoop on said frame and communicating with said turbine for driving said motor, means selectively mechanically connecting said air turbine to said motor;

e. said air scoop being forwardly directed, and including;

f. doors adapted to block said air scoop to reduce air resistance when said motor is driving said vehicle; and

g. said doors including means sensitive to the reduction of driving energy to said vehicle to operate said doors.

4. The vehicle as set forth in claim 3 wherein said air scoop comprises:

a. laterally directed air scoops adapted to receive crosswind energy for powering said turbine.

United States Patent [19]

Mead et al.

[11] 4,229,661

[45] Oct. 21, 1980

[54] POWER PLANT FOR CAMPING TRAILER

[76] Inventors: Claude F. Mead, 5072 Mt. Etna Dr., San Diego, Calif. 92117; William F. Holmes, 5515 Shasta La. #1, La Mesa, Calif. 92041

[21] Appl. No.: 13,044

[22] Filed: Feb. 21, 1979

[51] Int. Cl.[3] F03D 9/02

[52] U.S. Cl. 290/44; 290/52; 290/55

[58] Field of Search 290/1, 44, 52, 55

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Primary Examiner—J. V. Truhe

Assistant Examiner—W. E. Duncanson, Jr.

Attorney, Agent, or Firm—Henri J. A. Charmasson

[57] ABSTRACT

A power plant for mobile homes, camping trailers, and the like, capable of capturing low powered aeolian energy, storing said energy in the form of compressed air, and delivering it on demand in the form of household electrical current. The device comprises a wind turbine driving an air compressor which feeds a storage tank. On demand, the compressed air drives a turbine coupled to an electrical generator. Various pressure regulators are used to regulate the speed of the generator. The wind turbine is also coupled to an alternator which maintains a bank of electrical batteries charged. A DC motor running on the batteries is used when necessary to boost the drive of the air compressor during periods of heavy or long power drain. Provision is made for rapidly recharging the power plant from either a supply of compressed air or from an AC power source.

10 Claims, 4 Drawing Figures

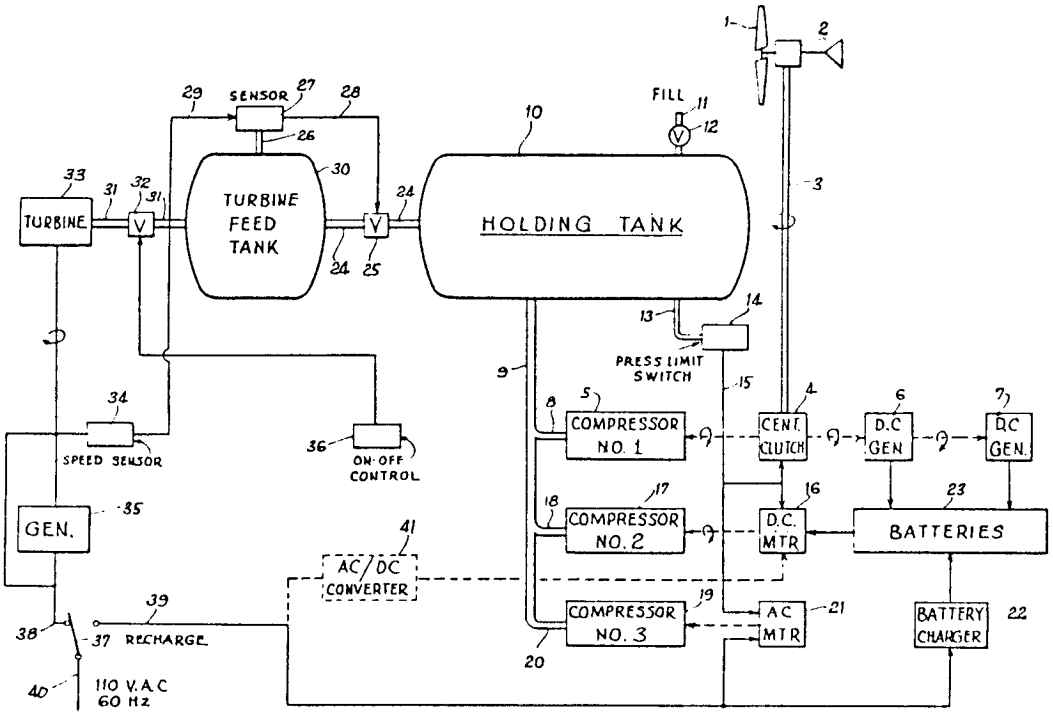


FIG. 1

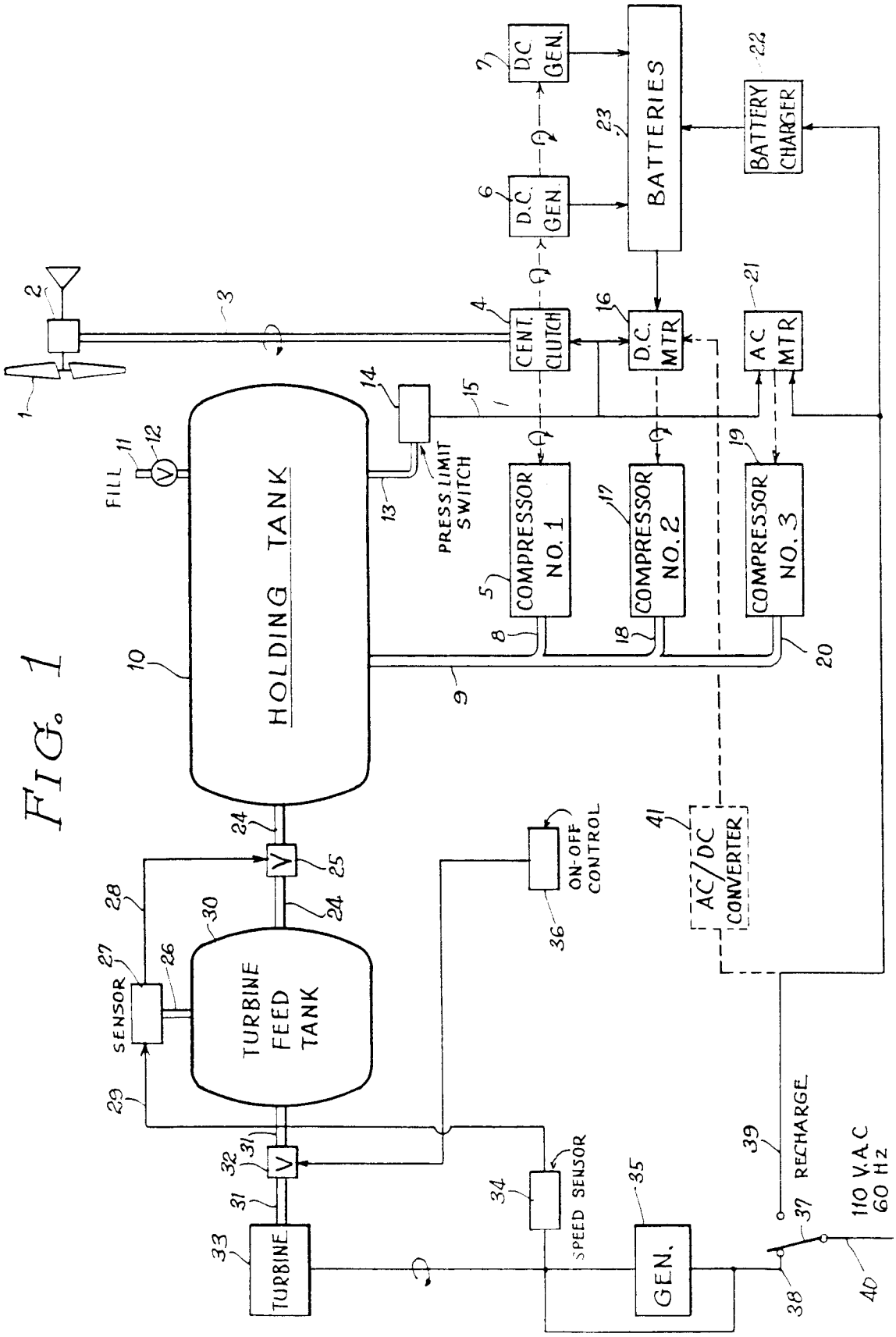

1
2
3
4
CENT. CLUTCH
5
COMPRESSOR NO. 1
6
D.C. GEN.
7
D.C. GEN.
8
9
10
HOLDING TANK
11
FILL
12
13
14
PRESS. LIMIT SWITCH
15
16
D.C. MTR
17
COMPRESSOR NO. 2
18
19
COMPRESSOR NO. 3
20
21
A.C. MTR
22
BATTERY CHARGER
23
BATTERIES
24
25
26
27
SENSOR
28
29
30
TURBINE FEED TANK
31
32
33
TURBINE
34
SPEED SENSOR
35
GEN.
36
ON-OFF CONTROL
37
RECHARGE
38
39
110 V.A.C 60 Hz
40
41
AC/DC CONVERTER

FIG. 2

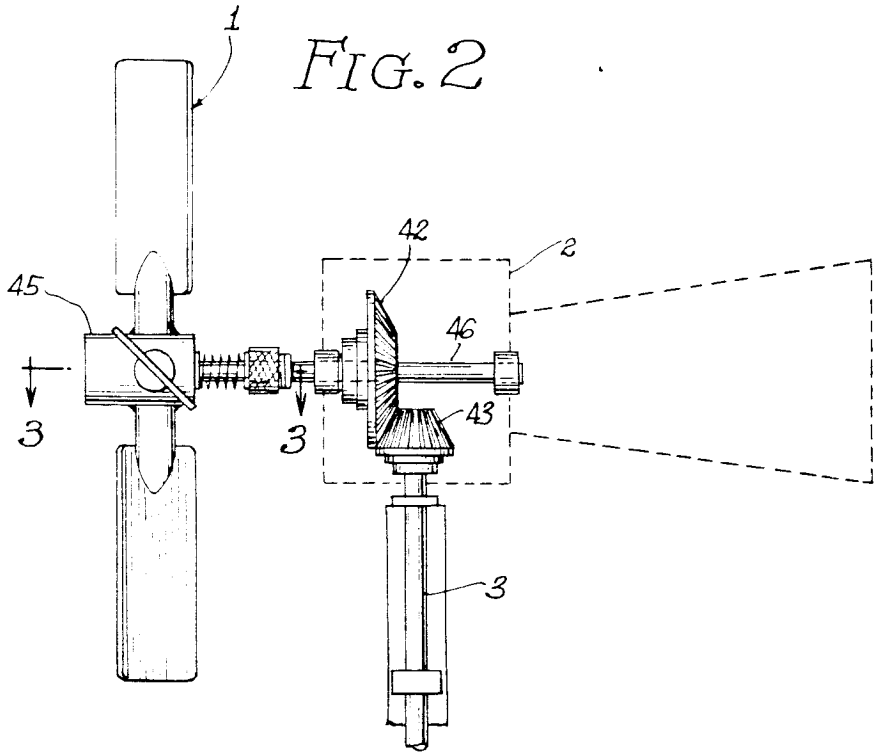


FIG. 3

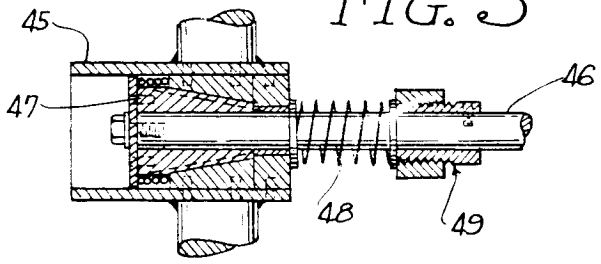
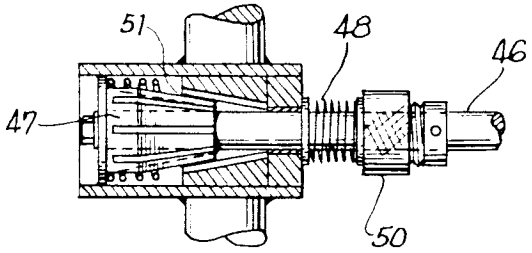


FIG. 4



POWER PLANT FOR CAMPING TRAILER

BACKGROUND OF THE INVENTION

The current shortage of fossil fuel and public concern for the quality of the environment have triggered a hurried search for alternate forms of energy. The capture and use of solar energy, and its derivative, wind power, is the object of many new inventions. Due to the inefficiency of the collector device and storage media, use of these forms of energy has been limited to low power stationery applications. Yet wind power should be adequate for any application requiring very low power or a short, occasional low to medium power supply of energy. These circumstances are encountered, for instance, in a refrigerated railroad car where occasional bursts of power are required to run the refrigerating system in order to maintain a low temperature inside the car. Similar circumstances are found in some mobile housing units such as a camping trailer. There, again, a supply of household current might be necessary for a short time between long periods of travel. In such instances, a system can be devised for accumulating energy generated by a wind turbine powered by the wind or by the air draft created by the motion of the vehicle. It is further desirable that the power system be replenishable from non-polluting energy sources which can be encountered along the travel route.

SUMMARY OF THE INVENTION

It is accordingly an object of the instant invention to provide a novel power plant for mobile homes, and the like, which captures aeolian energy, stores it in the form of compressed air, and delivers it on demand in the form of household electrical current.

Another object of this invention is to provide a power plant which does not discharge polluting effluents into the atmosphere.

Still another object of the invention is to provide a power plant which can be recharged by capturing the effect of the wind, or the effect of the air draft created by the movement of the vehicle.

A further object of the invention is to provide a power plant which can be recharged from a household current electrical outlet.

It is also an object of this invention to provide a power plant which can be replenished from a source of compressed air such as those found in automotive service stations.

An additional object of the invention is to provide a power plant which is responsive to a very low level of aeolian energy for a short period of time.

These and other objects are achieved by a power plant which comprises a wind turbine driving an air compressor. Theair supply by the compressor is stored in the tank and used on demand to activate a turbine. The turbine, in turn, is coupled to a generator which creates household current. The wind turbine is also coupled to generators which charge a series of electrical batteries. On occasions when the AC power drain requires it, a motor running on the batteries is used to boost the output of the air compressor. Provision is made for driving the compressor from an outside AC power source. The air tank has a separate inlet through which it can be replenished from a source of compressed air.

IN TTHE DRAWINGS

FIG. **1** is the general block diagram of the entire power plant;

FIG. **2** is a front elevation of the wind turbine and of its mechanical coupling to the drive shaft;

FIG. **3** is a cross-sectional view taken along line **3**—**3** of FIG. **2** showing the propeller linkage mechanism in the engaged position;

FIG. **4** is a view similar to the one illustrated in FIG. **3** but showing the propeller linkage mechanism in the disengaged position.

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Referring now to FIG. **1**, there is shown a diagramatical representation of the preferred embodiment of the invention. A wind turbine comprising a propeller **1** and an orthogonal coupling assembly **2** drives a shaft **3** connected to a centrifugal clutch **4**. This type of clutch is designed to engage itself when the speed of the drive shaft **3** reaches a certain minimum preset limit. The plate of the clutch is first connected to a compressor number **5** and second to a couple of DC generators **6** and **7**. Block **5** represents a adiabatic compressor requiring an input drive of approximately one-fourth horsepower. The output of the compressors **5** is protected by a check valve and leads into a pipe **8** connected to a tank inlet pipe **9**. The inlet pipe **9** feeds into a holding tank **10** capable of holding sixty gallons of compressed air under a maximum pressure of **200** pounds per square inch. The DC generators **6** and **7** supply a series of electrical batteries **23**. The batteries feed a DC motor **16**. The DC motor is in turn connected to a second compressor **17**. The second compressor **17** is similar to the first compressor **5** and is connected through to pipe **18** to the tank inlet pipe **9**. A third compressor **19** similar to the first and second compressors is also connected to the tank inlet pipe **9** through pipe **20**. The third compressor **19** is powered by an AC motor **21**. A pressure limit switch assembly **14** senses the pressure in the holding tank through a pipe **13**. A high pressure switch within the assembly **14** is activated when the holding tank reaches the maximum safely allowable pressure. This switch through line **15** causes the disengagement of the clutch **4** and turns off DC motor **16** and AC motor **21**. A second switch within the assembly **14** is activated when the holding pressure falls below a preset limit.

This second switch through line **15** turns on the DC motor **16**. It can now be seen that when the tank pressure is below the lowest limit, both the first and second compressors **15**, **17** will be activated. When the tank pressure goes above the lowest preset limit, only the first compressor **5** will be activated. If the holding tank pressure reaches the maximum tolerable limit all the compressors will be deactivated. The engagement speed of the centrifugal clutch **4** is set to a level corresponding to the minimum power necessary to drive the first compressor **5** and the DC generators **6** and **7**. If the speed of the wind falls below that level, the shaft **3** will be free-running. The holding tank **10** has a separate inlet **11** protected by a check valve **12**. The holding tank is connected to a turbine feed tank **30** through pipe **24** controlled by valve **25**. The turbine feed tank **30** is connected to the inlet of a turbine **33** through pipe **31** controlled by valve **32**. The turbine **33** is powered by the expansion of the compressed air supplied by the

turbine feed tank **30**. The turbine **33** is similar to the compressed air motors used in certain impactors and drills. The turbine drives an AC generator **35** designed to supply approximately five kilo volt amperes of household current at **60** Hertz and **110** volts. The turbine is turned on by means of the valve **32** controlled by an/off switch **36**. The speed of the turbine **33** is determined by the pressure of the air accumulated in the turbine tank **30**. The pressure is monitored by sensor **27** connected to the turbine feed tank **30** by pipe **26**. Sensor **27** contains a set of high and low limits. When the turbine feed tank pressure falls below the low limit, valve **25** is opened through control line **28**. When the pressure in the turbine feed tank **30** reaches the high limit, the valve **25** is closed. The high and low limit of sensors **27** are not fixed but subject to minor variations in response to the speed of the turbine **33**. The speed of the turbine **33** and of the generator **35** is monitored by speed sensor **34**. The output of the speed sensor **34** is inversely proportional to the speed of the turbine **33**. The speed sensor signal **29** is fed to sensor **27**. if the output frequency of the generator **35** deviates from the required 60 Hertz, the high and low limits of the sensor **27** are either increased or decreased. If the speed of the generator is slowed down by an increase in the load current, the high and low limits of sensor **27** are raised in order to raise the pressure in turbine feed tank **30**. The turbine **33** will respond to the pressure change by increasing its rotational speed. The output of the generator **35** is made available for use through lines **38** and **40** controlled by a switch **37**. The pressure in the holding tank **10** may be boosted from two external sources. First, compressed air may be introduced through inlet **11**. Second, the AC motor **21** may be connected to an external source of electrical energy through lines **39** and **40** controlled by switch **37**. The external electrical source may also be applied to a battery charger **22** which supplies the series of batteries **23**. In an alternate version of the preferred embodiment, it is suggested that an AC/DC converter **41** be used to drive the DC motor **16** from the external electrical supply. In such a case, the AC motor **23** and the third compressor **19** are not necessary. The power plant just described is primarily designed to be installed on board a camping trailer. This power plant will accumulate aeolian energy during the periods when the wind is blowing or the trailer is in motion. The energy is stored in two forms. First, it is stored in the form of compressed air in the holding tank **10**. Second, it is stored in the form of DC current in the series of batteries **23**. Both storage media are ecologically clean. Furthermore, the electrical system can boost the power of the compressed air system during periods of heavy power drain or long use. For added convenience, the system can be refueled from an external source of electrical energy such as a household outlet or from an external source of compressed air such as those found in service stations for use by automobilists. It should be noted also that this power plant is versatile in that it can be driven not only from the movement of fluids such as air or water, but also from the movement of the vehicle. In the later case, the shaft **3** would be coupled directly to the wheel of the vehicle.

Referring now to FIGS. **2** through **4**, there is shown the details of the propeller **1** and coupling box **2**. The propeller is noticeable by the fact that it is protected against bursts of wind which could damage the equipment. The hub **45** of propeller **1** is mounted on a shaft **46** by means of a conical spindle **46**. The hub has a central cavity **51** matching the outline of the spindle **47**. The hub **45** is held against the spindle by means of a coil spring **48** resting against an adjustable stop **49**. An excess of pressure of the wind against the propeller **1** will cause the hub **45** to be pulled back against the spring **48**, disengaging it from the spindle **47**. At that point the propeller **1** will rotate freely without driving the shaft **46**. The pressure of the coil spring **48** may be adjusted by turning the ring **50** around the threaded base of the stop **49**.

The various mechanical and electro-mechanical components of the power plant such as the centrifugal clutch, compressors, generators, turbines, valves and pressure-activated switches are well known to those skilled in the art.

The speed sensor **34** may be implemented with an electronic integrator whose output signal **29** amplitude is proportional to the frequency of AC generator **35**. The signal **29** is then used to modulate the sensitivity of sensor **27** switches. This technique is also well known to those skilled in the electro-mechanical arts.

Modifications, other than those suggested, can be made to the embodiment of the invention just described without departing from the spirit of the invention and the scope of the appended claims.

The invention claimed is:

1. A power plant which comprises:

(a) first rotating means responsive to movement of a fluid;

(b) first fluid compressor driven by the first rotating means;

(c) first means for coupling the first rotating means to the first fluid compressor;

(d) first electrical energy generator driven by the first rotating means;

(e) second means for coupling the first rotating means to the first generator;

(f) means for accumulating electrical energy generated by the first generator;

(g) second rotating means responsive to said accumulated energy;

(h) second fluid compressor driven by the second rotating means;

(i) means for storing compressed fluid;

(j) fluid conduit means for connecting the outputs of the first and second fluid compressors to the means for storing;

(k) means responsive to fluid pressure within the means for storing for controlling the operation of the first and second fluid compressors;

(l) third rotating means responsive to the expansion of compressed fluid;

(m) means for connecting the means for storing to the third rotating means;

(n) second electrical energy generator driven by third rotating means; and

(o) means for coupling the third rotating means to the second electrical energy generator.

2. The power plant claimed in claim **1** wherein the means for controlling the operation of the first and second fluid compressors comprise:

(a) first switch means responsive to high pressure for turning off the second rotating means and for inhibiting the first fluid compressor; and

(b) second switch means responsive to lower pressure for turning on the second rotating means.

3. The power plant claimed in claim **2** wherein the means for storing compressed fluid comprise:

(a) a high pressure tank;
(b) a low pressure tank;
(c) first valve means responsive to fluid pressure in the low pressure tank for regulating the flow of fluid from the high pressure tank to the low pressure tank; and
(d) the means for connecting the means for storing to the third rotating means comprise fluid conduit means and second valve means for controlling the flow of fluid.

4. The power plant claimed in claim **3** wherein said means for storing further comprise means responsive to the rotating speed of the third rotating means for controlling the first valve means.

5. The power plant claimed in claim **4** which further comprises:
(a) fourth rotating means responsive to electrical energy;
(b) third fluid compressor driven by the fourth rotating means;
(c) means for coupling the fourth rotating means to the third fluid compressor;
(d) means for connecting the third fluid compressor to the means for storing; and
(e) means for connecting the fourth rotating means to an external electrical energy source.

6. The power plant claimed in claim **4** wherein said means for accumulating comprise at least one electrical storage battery;
a battery charger connected to said battery, and
means for connecting said battery to an external electrical power source

7. The power plant claimed in claim **1** wherein said first rotating means comprise: Lp1 (a) a rotating shaft;
(b) a conical spindle at one end of the shaft;
(c) a propeller having in its hub a conical hole engaging said spindle;
(d) means for resiliently holding the propeller engaged around said spindle; and
(e) means for adjusting the pressure of the means for holding against the propeller.

8. The power plant claimed in claim **4** wherein the first means for coupling comprise a centrifugal clutch.

9. The power plant claimed in claim **7** installed into a vehicle.

10. The power plant claimed in claim **9** wherein said high pressure tank comprises a means for connecting said tank to an outside source of compressed air;
said means for accumulating electrical energy comprises at least one electrical storage battery;
said second rotating means comprise a DC motor;
said third rotating means comprise a turbine powered by expansion of compressed air;
said second electrical energy generator comprise a generator of household alternating current; and
means for distributing said household current to the vehicle electrical appliances.

* * * * *

—Staff photo by John Price

Air To The Future?

Oblivious to curious stares, Claud Mead drives Clairemont street in "air power" car he envisions will spare American motorists from gasoline woes. Theoretically, big version of car will get 600 miles to a tank of compressed air. (Story on B-5)

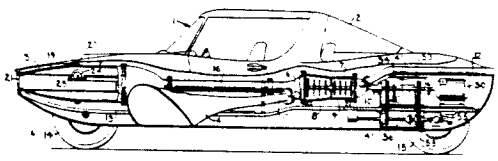
Claude Mead is no longer involved in air cars. He told our correspondent that when he started getting publicity about his air car, he was visited by two congressmen who informed him of the implications of what he was doing and asked him to disassemble his air car, which he did. He says there was an article in Windpower Digest about five years ago (1982?) about a project done by S.W. Research of San Antonio which closely resembled the system he patented for capturing the energy in low winds.

Mr. Mead is not disclosing his design secrets for air cars.

For possible updates on this information, contact David London, Box 560, Hollywood, Florida 33022.

see also Popular Mechanics February 1971, "Running on wind"

3,556,239
ELECTRICALLY DRIVEN VEHICLE
Joseph W. Spahn, 5007 N. Kensington, Kansas City, Mo.
Filed Sept. 23, 1968, Ser. No. 761,560
Int. Cl. B60l 11/14; B60d 9/00
U.S. Cl. 180—68 4 Claims



A battery powered automobile includes an air operated turbine fed by front and side air scoops for providing both charging current to the batteries and driving power for the automobile. An auxiliary internal combustion engine is included for use when necessary. Deceleration and wind sensitive controls operate door structure on the front air scoop so that it opens, increasing drag, only under predetermined conditions. Braking energy is utilized to help charge the batteries.

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(12) UK Patent Application (19) GB (11) 2 126 963 A

New Scientist, 10/25/84

Perpetual drive on air

BRITISH patent application 2 126 963, from Roger Brierley of Edinburgh, is an impressive document. In 26 sheets of technical drawings and 33 pages of text it describes how a car or train can be powered by air.

The patent invokes Bernoulli's theorem, Newton's laws, the Venturi effect and Maxwell-Boltzmann velocity distribution. But the invention still looks suspiciously like a clever reworking of an old perpetual motion idea.

A car, says the inventor, uses 50 per cent of its power to overcome air resistance. The car which Brierley describes is streamlined, and channels air into a tunnel with a small cross section where the air accelerates to a velocity higher than that of the moving vehicle. The high-speed air drives a turbine which is connected to a drive motor and batteries. "Excess energy produced at cruising speed would be stored for use during acceleration," says the inventor. Weight of the occupant saps energy during acceleration, but contributes momentum during cruising. "Hopefully," says Brierley, "these will cancel each other out and the occupants will have travelled on their journey for free in terms of energy usage".

Under the laws in force prior to 1978, the British Patent Office would automatically reject any application "contrary to well-established natural laws", because it wasted the examiners' time. The London Patent Office now seems more liberal in its policy. □

(54) **Air powered electrical vehicle**

(57) The invention is a method of producing electrical power in situ for use in the propelling of a moving vehicle through an air passage. This is achieved by streamlining the air of the air passage, then channelling the air through into a small cross-sectional area, by appropriate design of the vehicle, so that the air is accelerated to a relatively high velocity. substantially increased over that of the moving vehicle. The forward kinetic energy of the air stream is therefore increased in accordance with Bernoulli's theorem and is therefore capable of producing sufficient energy to not only overcome the air resistance of the vehicle but also most of the other drains on the power consumption of the vehicle, such as frictional forces.

The kinetic energy of the air stream so induced is harnessed by placing an air turbine system in the path of the air stream, in an optimised position towards the rear of the vehicle. A generator is connected to the air turbine and the electric energy produced is fed to an electric motor, which propels the vehicle. This electrical energy could either be fed directly to the motor or first be transferred to a battery storage system. Whilst there are a number of air turbine systems that could be employed with this invention a special dual turbine arrangement is described in the request specification.

(21) Application No 8201614
(22) Date of filing 20 Jan 1982
(43) Application published 4 Apr 1984
(51) INT CL³ B60K 1/00
(52) Domestic classification B7H A5
(56) Documents cited FR A 0877563 US 3556239 US 3878913 US 3374849
(58) Field of search B7H

(71) Applicant Roger Stuart Brierley, 10 Grosvenor Crescent, Haymarket, Edinburgh, E12 5EP
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Brierley's complete patent is included later in this book.

March 26, 1968 L. E. REDMAN 3,374,849

ELECTRIC VEHICLE

Filed Sept. 28, 1966 2 Sheets-Sheet 1

FIG. 1

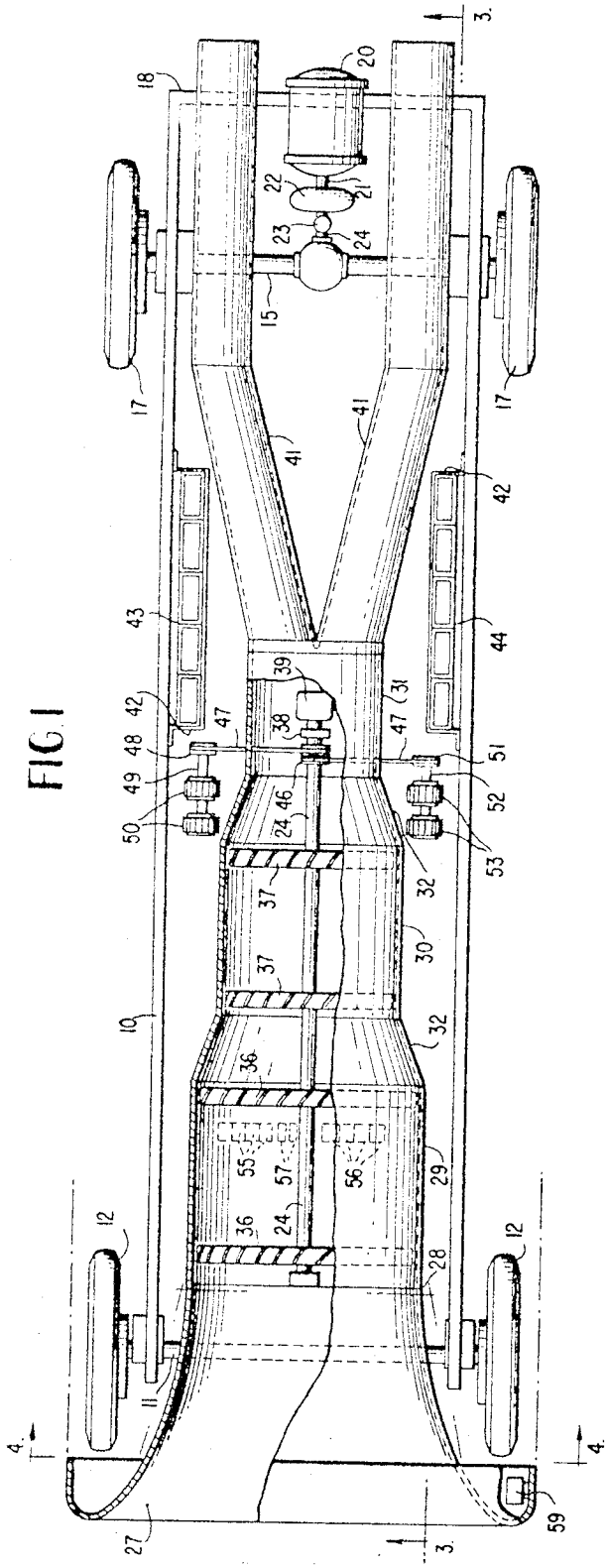
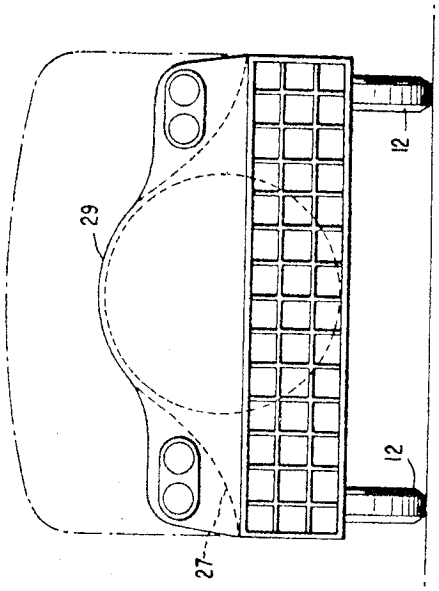


FIG. 2



INVENTOR

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BY Kenyon, Palmer, Stewart & Estabrook

ATTORNEYS

March 26, 1968 L. E. REDMAN 3,374,849

ELECTRIC VEHICLE

Filed Sept. 28, 1966 2 Sheets-Sheet 2

FIG. 3

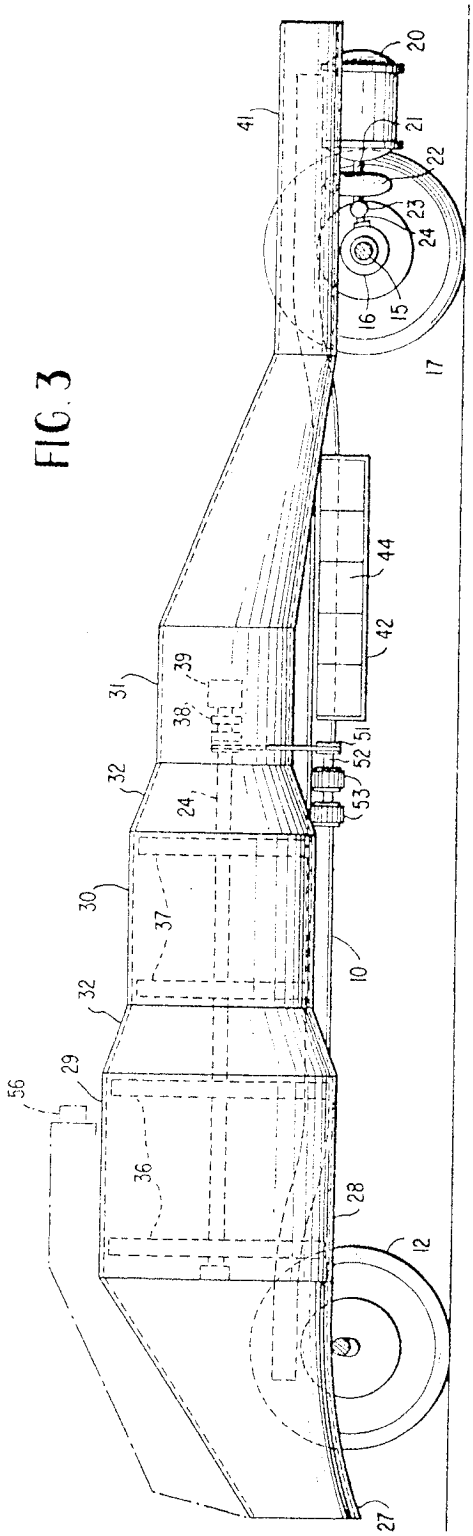
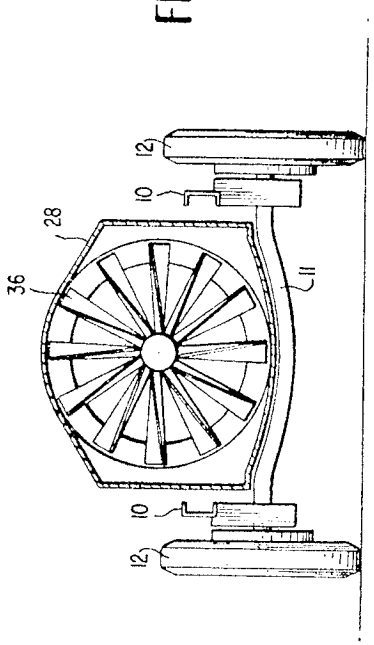


FIG. 4



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United States Patent Office 3,374,849 Patented Mar. 26, 1968

3,374,849

ELECTRIC VEHICLE

Lawrence E. Redman, 2005 E. Adams St., Phoenix, Ariz. 85034

Filed Sept. 28, 1966, Ser. No. 582,647
7 Claims. (Cl. 180—65)

This invention relates broadly to motor vehicles and more specifically to improvements in the propulsion system therefor.

One of the objects of the present invention is to provide an electric motor propelled vehicle having two banks of batteries with means for driving said motor by one bank of bateries while charging the other bank of batteries.

Another object is to provide an electric motor propelled vehicle having an air driven turbine mounted thereon which is connected to two banks of batteries for charging one bank of batteries while the other bank of batteries provides the motive power for propelling the vehicle.

Still another object is to provide an electric motor propelled vehicle having an air driven turbine mounted thereon and operatively connected to a plurality of alternators for charging a plurality of batteries with which to drive the electric motor.

Other objects and advantages more or less ancillary to the foregoing in the manner in which all of the various objects are realized will appear in the following description, which, when considered in connection with the accompanying drawings, sets forth the preferred embodiment of the invention.

Referring to the drawings wherein the preferred embodiment of the invention is illustrated:

FIGURE 1 is a plan view of a vehicle embodying the present invention with the body thereof having been removed in the interest of clarity;

FIGURE 2 is a front elevational view of the vehicle of the present invention with the forward portion of the body being illustrated in broken lines;

FIGURE 3 is a vertical sectional view of the vehicle embodying the present invention, the view being taken on the line 3—3 of FIGURE 1; and

FIGURE 4 is a vertical sectional view of the front end portion of the vehicle of the present invention, the view being taken on the plane 4—4 of FIGURE 1.

Referring to FIGURE 1, there is shown a vehicle frame 10 with an axle 11 mounted on the forward end thereof for rotatably supporting a pair of front wheels 12. The front wheels are provided with conventional steering arms and linkage, not shown, to facilitate the turning and guiding of said motor vehicle.

The rear end portion of the frame 10 has mounted thereon an axle housing 15 which is provided with a conventional differential unit 16 with the rear driving wheels 17 being connected to the axle housing 15. The rear end of the vehicle frame 10 is provided with a transverse member 18 which constitutes a support for an electric motor 20. The motor may be a DC motor of 15 HP and operating on 110 volts and said motor is provided with an output shaft 21 that is connected to an electrically actuated clutch member 22. The drive shaft of the clutch 22 is connected to a universal joint 23 that in turn is drivingly connected by a shaft 24 to the differential unit 16. Thus, upon energization of the motor 20 and actuation of the clutch 22, the rear wheels 17 of the vehicle will be rotatably driven through the differential unit 16 and axle housing 15 to propel the vehicle.

The forward end of the vehicle frame 10 has mounted thereon an enlarged air scoop 27 which has the configuration of a funnel and is of such a size as to extend across the forward end of the vehicle so as to substantially enclose or overlie the front wheels 12. The air scoop 27 merger into an elongated housing 28 that is formed with a plurality of communicating sections or areas 29, 30 and 31. The sections 30 and 31 are each of progressively smaller diameter than the preceding section or area and a tapered collar or portion 32 is employed to connect the several sections to one another. The sections 29, 30 and 31 have positioned therein a shaft 35 which is mounted upon suitable supports, not shown, for rotative movement within said housing. The forward end portion of the shaft 24 within the section 29 of the housing 28 has mounted thereon turbine elements or fan members 36 that are arranged in spaced relation to one another and which are of a diameter slightly less than the internal of said section. The section 30 of the housing 28 is also provided with a pair of spaced turbine elements or fan members 37 mounted on the shaft 21 which are of a diameter slightly less than the internal diameter of the section. The shaft 24 terminates within the section 31 of the housing 28 and an electrically actuated clutch member 38 is connected to the end thereof. The clutch member 38 is in turn connected to an electric motor 39 for imparting initial rotation to the shaft 24 and the turbine elements mounted thereon.

The section 31 of the housing 28 has connected thereto a bifurcated exhaust or passageway system consisting of a pair of tubular conduits 41 which project outwardly beyond the rear end of the vehicle and are supported upon the transverse member 18. These conduits permit the air which has entered the housing 28 and moved through the various sections thereof, for rotating the turbine elements, to be discharged at the rear of the vehicle. The vehicle frame 10 has mounted on each side thereof a suitable bracket or support 42 for the reception of five storage batteries of 24 volts each. This arrangement constitutes a right bank of batteries 43 and a left bank of batteries 44 which are connected by suitable cables, not shown, to the electric motor 20. The two banks of batteries are provided with suitable controls, not shown, to facilitate the connection of one bank of batteries to the motor 20 while disconnecting the other bank of batteries from the motor 20 so that through said controls both banks of batteries may be disconnected from the motor 20 when the vehicle is not in operation, while first one and then the other bank of batteries may be connected to the motor 20 while the vehicle is being operated.

The shaft 24 adjacent the clutch member 38 in the housing section 31 has a pair of pulleys 46 mounted thereon for rotation therewith. Each of the pulleys 46 has a belt 47 entrained thereabout with one of the belts engaging a pulley 48 that is secured to a shaft 49 which is supported on the right side of the vehicle frame 10. The shaft 49 also has a pair of alternators 50 affixed thereon in spaced relation to one another for rotation with said shaft and pulley. The other belt 47 is likewise connected to a pulley 51 that is secured to a shaft 52 which has a pair of alternators 53 mounted thereon in spaced relation to one another. The alternators 50 are connected to the right bank of batteries 43 while the alternators 53 are connected to the left bank of batteries 44. The top of the housing 28 above the section 29 has mounted thereon, by any suitable means, a bank of four switches 55 for controlling the four alternators 50 and 53 while four voltage regulators 56 are provided for the four alternators. There is also provided on top of the housing 28 a pair of rheostats 57 which are connected to the right and left bank of batteries. The forward inturned end portion of the air scoop 27 has mounted thereon, by suitable

brackets, not shown, a conventional battery charger 59 that is connected to the two banks of batteries to facilitate the charging of said batteries when the vehicle is not operating by connecting the battery charge 59 to a suitable source of electric current.

In the use of the vehicle of the present invention, the motor 39 is energized and the clutch 38 is actuated so as to initiate rotation of the shaft 24 and the turbine elements 36 and 37. This rotation of the shaft 24 will also drive the alternators 50 and 53. The motor 20 is then energized by connecting it to one of the banks of batteries after which the clutch 22 may then be actuated for driving through the differential unit 16 the vehicle wheels 17 and moving the vehicle forwardly. As the vehicle is moved forwardly by means of the motor 20, air will be directed into the housing 28 by means of the scoop 27 and the air in moving through the housing 28 will rotate the turbine elements 36 and 37 in the compartments or sections 29 and 30 and the air will then flow through the compartment 30 and into the conduits 41 from whence it will be exhausted at the rear of the vehicle. As the air moves through the housing 28, it will continue to rotate the turbine elements 36 and 37, thus permitting the clutch 38 to be disengaged and the motor 39 turned off as the rotation of the turbine elements 36 and 37 will drive the alternators 50 and 53. Assuming that the motor 20 is being run by the right bank of batteries 43 so that through the switches 55 the left bank of batteries may be charged and when the right bank of batteries 43 become weak and incapable of driving the motor 20, the left bank of batteries 44 may then be cut into operation for driving the motor 20 while the right bank of batteries 43 may then be charged by the alternators 50 and 53. In this manner, one bank of batteries will be charged by the alternators while the other bank of batteries is used for driving the motor 20 and the charging of the bank of batteries by the alternators will be accomplished by the rotative movement of the turbine elements 36 and 37 within the housing 28. The rotation of the turbine elements, of course, is accomplished by means of the air moving through the housing from the scoop 27 and into the conduits 41 from whence it will be exhausted at the rear of the vehicle.

In the foregoing manner the vehicle can be operated by means of the electric motor 20 wherein one bank of batteries is used to supply power to the motor while the other bank of batteries is being charged by the alternators. The banks of batteries may be reversed when one bank becomes incapable of driving the motor 20, so that by alternately charging the banks of batteries and driving the electric motor off of the bank of batteries that is not being charged, the vehicle may be propelled over a roadway to insure that the air stream moving through the scoop 27 and housing 28 will drive the turbine elements. The continued rotation of the turbine elements by means of the air flowing through the housing permits the alternators to charge one bank of batteries while allowing the vehicle to move forward by means of the motor 20 being operated from the other bank of batteries.

Although the foregoing description is necessarily of a detailed character, in order that the invention may be completely set forth, it is to be understood that the specific terminology is not intended to be restrictive or

confining and that various rearrangements of parts and modifications of detail may be resorted to without departing from the scope and spirit of the invention as herein claimed.

What is claimed is:

1. In a vehicle having a frame and a pair of driving wheels, an electric motor mounted on said frame and connected to said wheels for rotatably driving same, a support mounted on each side of said vehicle frame, a bank of batteries in each support, an air scoop at the forward end of said frame, an elongated housing communicating with said scoop, a plurality of turbine elements positioned in said housing for rotation therein, a plurality of alternators driven by said turbine elements and control means for connecting said electric motor to one of said bank of batteries for driving said vehicle while connecting the other bank of batteries to said alternators for replenishing the charge in said other bank of batteries upon the rotation of said turbine elements.

2. In a vehicle of the type as defined in claim 1 wherein said frame has mounted thereon a battery charging unit connected to said banks of batteries; said unit having means for connecting same to a source of power for charging the banks of batteries when said vehicle is not in use.

3. In a vehicle of the type as defined in claim 1 wherein said elongated housing is formed with a plurality of sections progressively smaller in diameter with the last section connected to a bifurcated exhaust conduit system, and at least two sections of said housing having turbine elements positioned therein.

4. In a vehicle of the type as defined in claim 3 wherein said turbine elements are mounted on a shaft in said housing with an electric motor connected to said shaft by a clutch element for rotating said shaft and alternators prior to and during the initial movement of said vehicle by said electric motor mounted on said frame.

5. In a vehicle of the type as defined in claim 4 wherein said shaft is provided with a pair of pulleys for driving said alternators by means of a pair of belts.

6. In a vehicle of the type as defined in claim 5 wherein said housing has a plurality of switches mounted thereon for controlling said alternators whereby said alternators upon the rotation of said turbine elements will charge one bank of batteries while the other bank of batteries will be rotating said electric motor for driving said vehicle.

7. In a vehicle of the type as defined in claim 1 wherein said air scoop is formed with an enlarged portion substantially encompassing the forward end of the vehicle frame and a grill element positioned across said enlarged portion.

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May 20, 1969 N. J. WATERBURY **3,444,946**

SELF-ELECTRIC-POWERED VEHICLE

Filed Oct. 3, 1966 Sheet 1 of 4

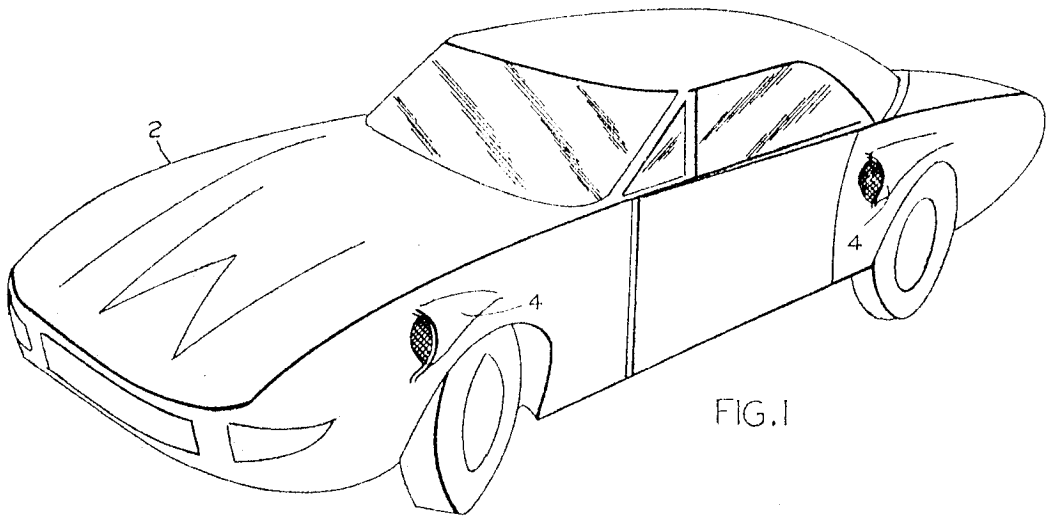

FIG. 1

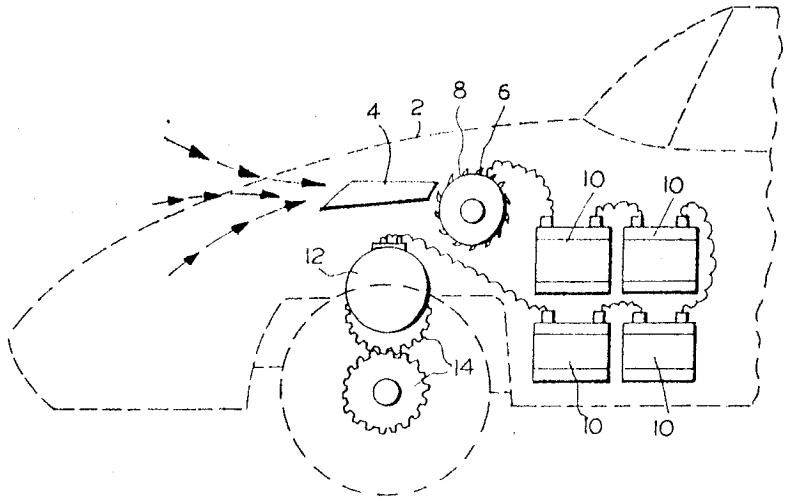

FIG. 2

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May 20, 1969 N. J. WATERBURY 3,444,946

SELF-ELECTRIC-POWERED VEHICLE

Filed Oct. 3, 1966 Sheet 2 of 4

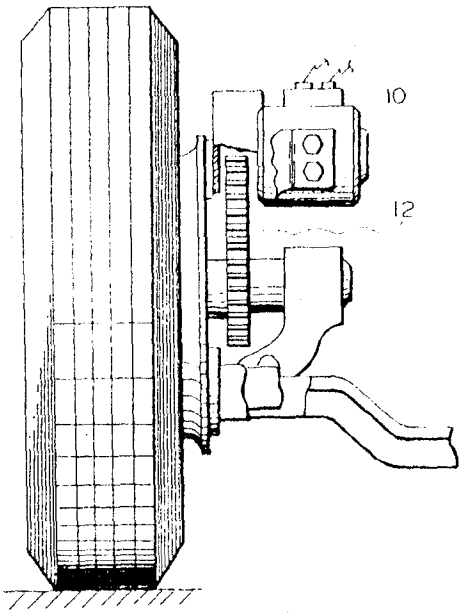

FIG.6

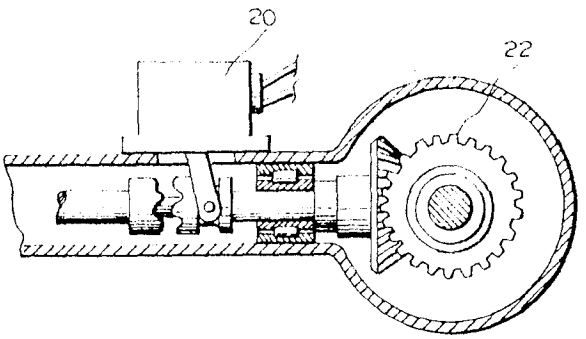

FIG.5

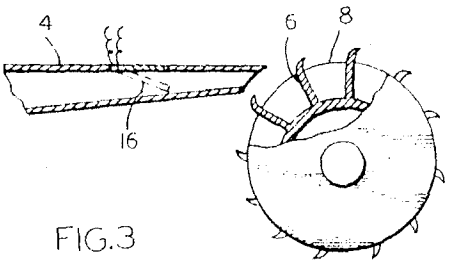

FIG.3

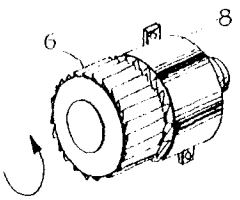

FIG.4

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SELF-ELECTRIC-POWERED VEHICLE

Filed Oct. 3, 1966 Sheet 3 of 4

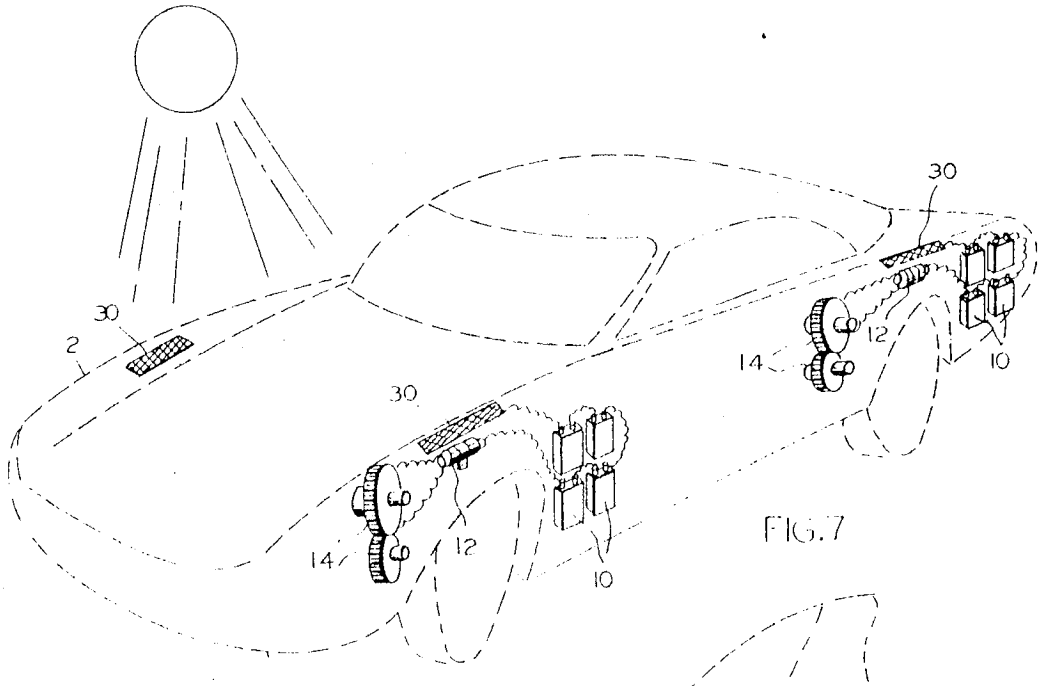

FIG.7

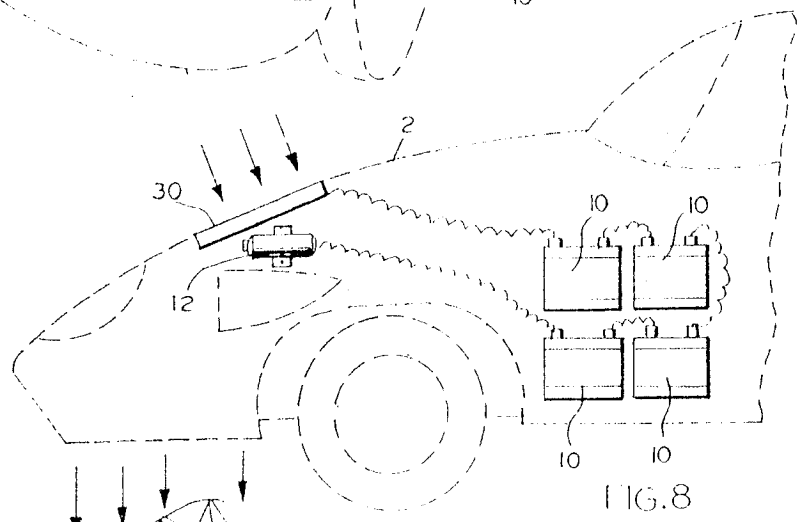

FIG.8

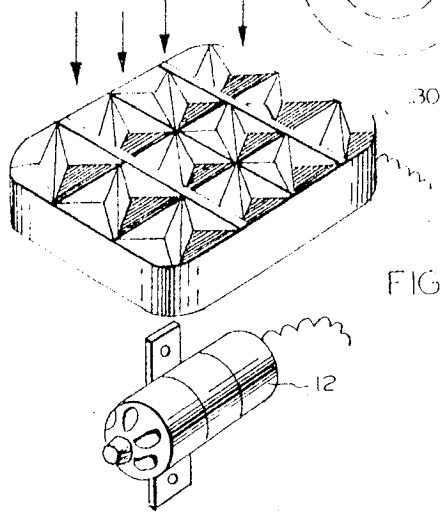

FIG.9

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May 20, 1969 N. J. WATERBURY 3,444,946

SELF-ELECTRIC-POWERED VEHICLE

Filed Oct. 3, 1966 Sheet 4 of 4

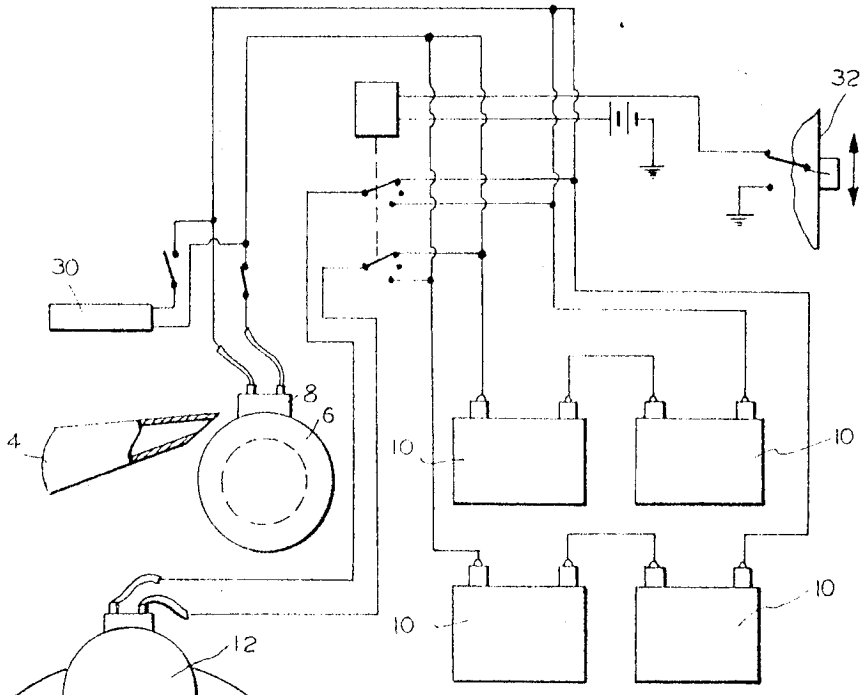

FIG.10

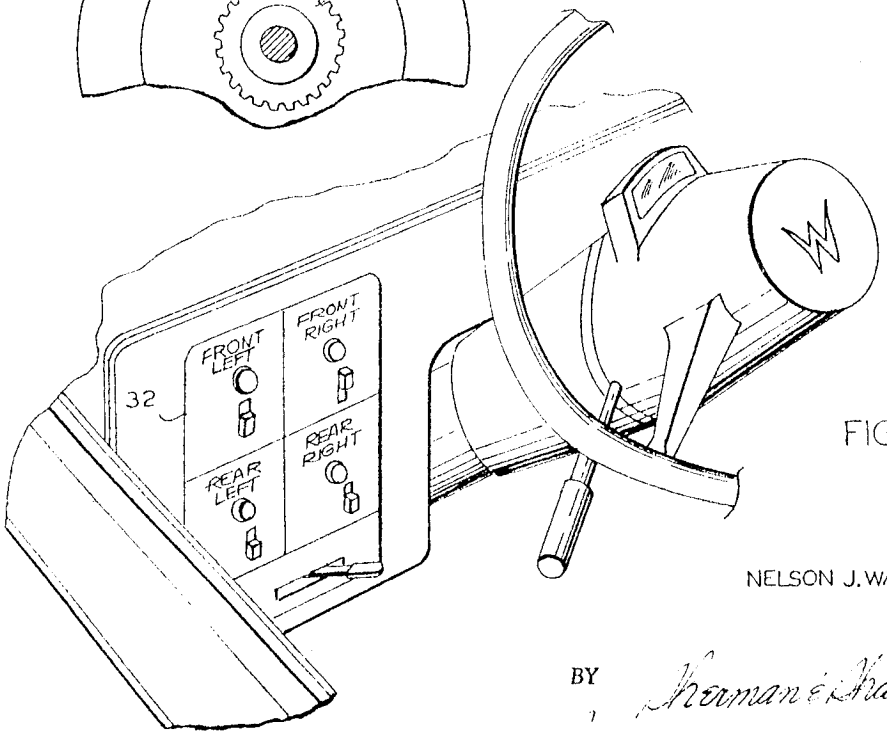

FIG.11

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United States Patent Office

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Patented May 20, 1969

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3,444,946

SELF-ELECTRIC-POWERED VEHICLE

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Filed Oct. 3, 1966, Ser. No. 583,889
Int. Cl. B60k 1/02, 1/04; B60l 11/18
U.S. Cl. 180—65 6 Claims

ABSTRACT OF THE DISCLOSURE

An electric motor driven vehicle having at least one electric motor to supply power to said vehicle, the improvement which comprises a system associated with each electric motor to supply electric power thereto comprising batteries arranged in series, and either a solar cell supplying energy to said batteries, a power-generating means with paddle wheel and venturi tube or both adapted to supply power to said batteries. The above combination may be used either alone or in conjunction with a conventional internal combustion engine.

The present invention relates to an automobile, boat or other vehicle that may be driven by electric power or a combination of electric power and gasoline power, and, more particularly, to an automobile in which electric motors are powered by batteries, which batteries are charged by the action of air currents, sunlight, or a combination of both.

In recent years, air pollution has become an ever increasing problem, especially in the area around and in large cities. The automobile is considered as the major factor in creating this problem of air pollution, the automobile contributing approximately 80% to 90% of all of the air pollution found in and around large metropolis areas.

The carbon monoxide gases and other poisons that are spewn in the atmosphere by gasoline-driven vehicles post a serious threat to life expectancy. The life of the people of today is being shortened, according to reports, from seven to ten years because of such air pollution.

Carbon monoxide gases are said to be one of the main causes of lung cancer, emphysema, heart disease and serious eye trouble as well as the dizzyness that often causes a driver to have a serious or fatal accident while operating a vehicle.

Various attempts to eliminate the air pollution problem associated with the noxious and poisonous fumes given off by an automobile have not been completely successful. Thus, for example, attempts have been made to install an after-burner device on the exhaust of an automobile so that the fumes that are egiven off by the burning of the gasoline will not be expelled directly into the atmosphere but will be subsequently burned to produce less noxious materials. While such devices have in some instances eliminated some of the problem associated with the fumes given off by automobiles, such after-burner devices have not been completely successful since it is impossible to completely eliminate all of the noxious material that is expelled to the atmosphere. Thus, even with such materials, there still is expelled to the atmosphere sufficient noxious and poisonous material tending to create serious air pollution problems.

In recent years there has been considerable experimentation with an electric car. Electric cars, per se, have been known for years. These include the small battery-operated vehicles such as golf carts, which need to be plugged in to a power source over night in order to charge the battery so that they can be employed. Attempts to apply this principle to larger cars requiring greater power sources have not beeen successful since it has not been found possible to apply a great enough power source in order to charge the battery necessary to supply the electric power for the running of the automobile without greatly inconveniencing the driver from a time standpoint. Thus, while the concept of employing electric power is known in the operation of automobiles, such electric power has not been successfully utilized in the operation of standard size automobiles because of the lack of a method, or means, to charge the batteries necessary to supply the electric power for the running of the automobiles.

2

In accordance with the present invention, however, a system which charges and maintains a full charge on batteries to operate an electric motor for the running of an automobile has been discovered. By the use of such system to charge and maintain the charge on batteries, it is possible to run a vehicle successfully on electric power without the use of a gasoline engine, thereby eliminating the noxious and poisonous fumes which are expelled to the atmosphere by the employment of a gasoline engine. The unique system discovered comprises the employment of an air scoop or vent or venturi tube which supplies air to a paddle wheel to run a generator or alternator which supplies the electric charge for the batteries necessary to run the electric motor-driven automobile. In a further embodiment, the present invention comprises the employment of a solar cell which supplies the charge to the battery by the employment of sunlight. In a further embodiment of the present invention, the batteries to be employed to drive electric motors of the automobile are charged, and the charge maintained by the combination of a solar cell obtaining energy from sunlight, and a generator or alternator driven by a paddle wheel in connection with a venturi tube through which air is drawn. The batteries employed are generally encased in a fender well, or recess, behind each wheel, each fender containing four batteries, two of which are in operation while the other two are being charged. These batteries in the fender well behind each wheel drive an independent electric motor associated with each wheel of the vehicle.

It is, therefore, a principal object of the present invention to provide an electric motor-driven vehicle which is free from the inherent deficiencies of previous vehicles.

It is a further object of the present invention to provide an electric motor-driven vehicle which electric motor-driven vehicle eliminates the noxious and poisonous fumes associated with the exhaust of gasoline-driven vehicles.

It is still a further object of the present invention to provide an electric motor-driven automobile in which an electric motor associated with each wheel of the vehicle is driven by batteries in series, which batteries are charged by the employment of an alternator, or generator, associated with a paddle wheel and venturi tube through which air is drawn.

It is yet a further object of the present invention to provide an electric-driven motor automobile wherein the batteries which drive the electric motor associated with each wheel of the vehicle are charged by the use of a solar cell obtaining energy from sunlight.

It is still a further object of the present invention to provide an electric motor driven automobile wherein the batteries which drive the electric motor in association with each wheel of the vehicle are charged by a combination of a solar cell obtaining its energy from sunlight, and an alternator, or generator, associated with a paddle wheel and a venturi tube through which air is drawn.

Still further objects and advantages of the vehicle of the present invention will become more apparent from the following more detailed description of the present invention and the accompanying drawings, wherein:

FIGURE 1 is a perspective view showing a vehicle of the present invention;

FIGURE 2 is a cross-sectional view of such vehicle showing the electric motor operating system of the present invention;

FIGURE 3 is an enlarged view in cross section showing the battery-charging means of the present invention;

FIGURE 4 is a further enlarged view of a generator, or alternator, containing a paddle wheel for the charging of the batteries in accordance with the present invention;

FIGURE 5 is a cross-sectional view of a drive shaft in accordance with the present invention;

FIGURE 6 is a view showing an electric motor drive mechanism for the vehicle wheel, in accordance with the present invention;

FIGURE 7 is a view showing a further embodiment of the present invention;

FIGURE 8 is a further view showing such further embodiment of the present invention;

FIGURE 9 is an enlarged view showing a solar cell and motor in accordance with the present invention;

FIGURE 10 is a schematic view of a circuit employed in operating the electric motors of the present invention; and

FIGURE 11 is a view illustrating an automobile control panel employed to control the electric motors of the present invention.

In the various figures, like numerals represent like elements throughout.

In FIGURE 1 there is represented an automobile **2**. As shown in FIGURE 2, the automobile has embodied in the fender, an air scoop in the form of a venturi tube **4**. When the vehicle is in motion, the air rushes through the venturi tube or orifice **4**, and impinges upon a flywheel or paddle wheel **6**, which is aligned in the path of the air passing through the venturi tube **4**. Such flywheel or paddle wheel **6** is attached to an alternator or generator **8**, so that the rotational movement of the flywheel **6** caused by the impinging air from the venturi tube or orifice **4**, causes the alternator or generator **8** to spin, thereby producing electrical energy supplied to batteries **10** located within a recess, or well (not shown) in the fender of the vehicle. In general, four batteries, arranged in series, are employed in each fender of the vehicle so that while two batteries are being charged, the remaining two batteries can be employed as a source of energy to operate an electric motor **12** associated with each wheel of the vehicle **2**. The electric motor **12** operates to work gears **14**, which gears can be arranged on the drive shaft of the vehicle, or can be directly attached to the wheel thereof. By the use of this system for operating an electric motor associated with each wheel of the vehicle, it is possible to run a vehicle such as an automobile, without the employment of gasoline. This is because the air impinging the flywheel **6** attached to the alternator or generator **8** will cause the batteries **10** to be charging so that there will be a constant and full supply of power for running the electric motors associated with the wheels of the vehicle. Therefore it will not be necessary to plug in the vehicle, or use any auxiliary source of power or energy for charging the batteries **10**. In order that the batteries **10** do not become overcharged, a valve **16** is placed in the venturi tube or orifice **4**, as shown in FIGURE 3. This valve **16** can be automatically controlled so as to shut off the supply of air to the flywheel **6** and attached generator **8**, thereby allowing the energy stored in the batteries **10** to be utilized to operate the electric motor **12** without further charging of such batteries. The valve **16** can be automatically controlled by an electric switch (not shown) operated by the driver of the vehicle when an indicator (not shown) shows the batteries **10** to be charged to the desired level.

FIGURE 4 illustrates how the flywheel or paddle wheel **6** is attached to the alternator or generator **8**, such that the rotational movement of the alternator or generator **8** caused by the impinging air from the venturi tube or orifice **4** causes the generator or alternator **8** to spin, thereby supplying electrical energy to the batteries **10**. As stated

previously, in most instances, four batteries are placed in a well or recess in each fender of the auttomobile so that while two batteries are operating by supplying electrical energy to drive the electric motor associated with each wheel of the vehicle, the remaining two batteries can be charging. It is not necessary that such batteries be any specific type of battery since any conventional battery employed in automobiles, boats, etc., (i.e., four-volt, six-volt, twelve-volt, etc.) can be employed. A particularly preferred battery is a nickel-cadmium battery, which battery is capable of supplying a great deal of power without being too great in size.

In accordance with the present invention, it is possible to operate the vehicle with less than all four of the electric motors operating. In other words, it is possible to have one, two, three or four of the electric motors in the vehicle operating at any one particular time. Thus, FIGURE 5 illustrates an electric switch **20**, which electric switch controls the operation of the motor associated with the drive shaft **22** and wheel of the vehicle. When it is desired to eliminate one electric motor, it is necessary only to throw such control switch on a dashboard-located control board.

FIGURE 6 is an enlarged view illustrating the location of the motor **12** and gearing **14** associated with the wheel of the vehicle in accordance with the present invention. As shown in this figure, each wheel of the vehicle has associated therewith a small electric motor **12**, which small electric motor **12** operates through gears **14** to rotate the wheel and cause the vehicle to move.

FIGURE 7 illustrates an alternative embodiment of the present invention. In such alternate embodiment of the present invention, the vehicle **2** is driven by a small electric motor **12** driving gear **14**, which electric motor **12**, associated with the wheel of the vehicle, is operated by batteries **10**, which batteries **10** are charged by a solar cell **30** located in the fender of the vehicle. This solar cell **30** can be any of the conventional cells which convert solar energy into electrical energy. Exemplary of such materials are the group of solar cells known as photovoltaic cells. The electrical energy produced by the solar cell **30** is employed to charge the batteries **10** in a recess, or well, located in the fender of the vehicle. Again, it is advantageous to employ four batteries so that the two can be charging while the other two are employed to operate the electric motor **12** associated with each wheel of the vehicle.

FIGURE 8 is a further representation of this alternate embodiment of the present invention showing the relationship of the solar cell **30**, the batteries **10**, and the electric motor **12**. The solar cell **30** and the electric motor **12** are shown in a further enlarged view, FIGURE 9.

While these embodiments have been described primarily in the alternative, it is important to note that they can be employed alternatively as a source of electric power for the vehicle, or can be employed together so as to provide reserve power for the automobile. In other words, by the conjoint use of these two systems for charging batteries to drive the electric motor associated with the wheel of the vehicle, it is possible to prevent a shortage of power that may be present because of an unexpected failure of either of the systems. An electrical circuit showing the conjoint, or alternative, use of these two systems for the charging of the batteries to supply the electric power for the automobile is shown in FIGURE 10.

In addition to the alternative, or conjoint, employment of these two systems for charging the batteries of the present invention, it is possible to employ one or both of these systems in conjunction with a conventional gasoline engine. In other words, it is possible to employ, in addition to one or more of these systems for the operation of an automobile or other vehicle, a conventional gasoline engine which can be put into operation in case of an electrical failure. Moreover, the systems of the present invention can be employed as a back-up system for a con-

ventional gasoline engine, which electrical systems can be made operational in case of a failure in the gasoline engine of the vehicle. Because of the great health hazard associated with the employment of a gasoline engine and the associated noxious and poisonous fumes given off to the atmosphere, it is, of course, preferred to employ the electrical system for operating the automobile as the principal system of operation of the automobile, with the gasoline system employed only as a back-up system, or auxiliary system, for use in case of an unexpected failure in the electrical operation of the automobile. Because of the fewer working parts, i.e., fan belts, pistons, etc., however, associated with the electrical operation of the automobile failure of such electrical operation will occur much less frequently than occurs by the use of a conventional gasoline engine in the operation of a vehicle. The employment of a solar cell as a source of energy for the charging of batteries is an additional factor which tends to prevent loss of electrical power when the automobile remains for a substantial length of time without being driven. The use of a gasoline engine will necessitate use of conventional gearing connections including drive shaft means, clutch, differential gear means for a wheel or wheels of the vehicle.

When great speeds are desired, it may be advantageous to employ a combination of gasoline power and electrical power so as to prevent a substantial drain on the electrical system of the automobile. Even when the vehicle is operating on gasoline power alone, which may be desired in some instances, it is important to note that the batteries are being constantly charged so as to always maintain a full supply of power for immediate operation of the vehicle by the electrical system. Since these batteries are therefore fully charged at all times, there is no problem starting the automobile after it has not been used for a substantial period of time.

FIGURE 11 illustrates a typical control panel **32**, which can be employed on a dashboard of a vehicle driven by electric power in accordance with the present invention. Such control panel can operate to disengage one or more of the electric motors of the vehicle when such are not necessary for operation. Thus, when the vehicle is being driven in city traffic at a relatively slow speed, it may not be necessary to operate on not more than one or two of the four electric motors, and thus the life of the electric motors can be greatly increased. This similarly increases the life of the batteries.

While the systems of the present invention have been described primarily with respect to automobiles, it should be understood that other land vehicles, e.g., buses, etc., can be similarly equipped with the electric power systems of the present invention. Furthermore, the nature of the present invention is such that air and sea vehicles can be similarly equipped.

Moreover, while the present invention has been primarily described by reference to an electric powered vehicle wherein each wheel thereof has an electric motor associated therewith, the electrical power system of the present invention can be similarly utilized in a vehicle containing only one, two, or three electric motors. For example, a single electric motor associated with the drive shaft of the vehicle can be advantageously powered by the electrical power generating systems of the present invention. Thus, a single electric motor can be powered by batteries arranged in series which batteries are charged by a combination of venturi tube and alternator or generator and attached paddle wheel, a solar cell, or a combination of such systems.

Accordingly, while the present invention has been directed primarily to certain preferred embodiments, it is to be understood that the present invention is in no way to be deemed as limited thereto, but should be construed as broadly as all or any equivalents thereof.

Having adequately described my invention, what is desired to be protected by Letters Patent is:

1. In an electric motor-driven vehicle wherein each wheel of the vehicle is provided with at least one electric motor to supply power for said vehicle, the improvement which comprises an individual system associated with each electric motor to supply electric power thereto comprising batteries charged by electric power generating means, a paddle wheel element attached thereto, and a venturi tube formed in the body of said vehicle, said venturi tube and paddle wheel element being so aligned that air through said orifice impinges upon said paddle wheel element to rotate same and operate said power generating means, a separate control for each said motor for independently operating each individual motor, and means for shutting off the air flow through each venturi tube.

2. The electric motor-driven vehicle of claim **1** wherein said vehicle further contains a conventional gasoline driven engine for auxiliary power which engine is connected by drive shaft means to at least one wheel of the vehicle.

3. In an electric motor driven vehicle wherein each wheel of the vehicle is provided with at least one electric motor to supply power for said vehicle, the improvement which comprises an individual system associated with each electric motor to supply electric power thereto comprising batteries arranged in series, said batteries charged by electric energy supplied by solar cells placed in the body of said vehicle and by electric power generating means, a paddle wheel element attached thereto, and a venturi tube formed in the body of said vehicle, said venturi tube and paddle wheel wheel being so aligned that air through said tube impinges upon said paddle wheel element to rotate same and operate said electric power generating means, and wherein each motor of said vehicle further has a motor control for independently operating the individual electric motors associated with each wheel of said vehicle.

4. Electric motor driven vehicle of claim **3** wherein said vehicle further contains a conventional gasoline driven engine for auxiliary power which engine is connected by drive shaft means to at least one wheel of the vehicle.

5. In an electric motor-driven vehicle wherein each wheel of the vehicle is provided with at least one electric motor to supply power for said vehicle, the improvement which comprises an individual system associated with each electric motor to supply electric power thereto, comprising batteries arranged in series, said batteries charged by electric energy supplied by one or several of a plurality of sources including solar cells, an alternator, and a generator selectively adapted to be arranged in series with said battery and with each other and placed in the body of said vehicle, wherein each said motor is provided with a separate control for independently operating each said motor.

6. The electric motor-driven vehicle of claim **5** wherein said vehicle further contains a conventional gasoline driven engine for auxiliary power which engine is connected by drive shaft means to at least one wheel of the vehicle.

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U.S. Cl. X.R.

290—54

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(22) Date of filing 20 Jan 1982
(43) Application published
4 Apr 1984
(51) INT CL³
B60K 1/00
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(54) **Air powered electrical vehicle**

(57) The invention is a method of producing electrical power in situ for use in the propelling of a moving vehicle through an air passage. This is achieved by streamlining the air of the air passage, then channelling the air through into a small cross-sectional area, by appropriate design of the vehicle, so that the air is accelerated to a relatively high velocity, substantially increased over that of the moving vehicle. The forward kinetic energy of the air stream is therefore increased in accordance with Bernoulli's theorem and is therefore capable of producing sufficient energy to not only overcome the air resistance of the vehicle but also most of the other drains on the power consumption of the vehicle, such as frictional forces.

The kinetic energy of the air stream so induced is harnessed by placing an air turbine system in the path of the air stream, in an optimised position towards the rear of the vehicle. A generator is connected to the air turbine and the electric energy produced is fed to an electric motor, which propels the vehicle. This electrical energy could either be fed directly to the motor or first be transferred to a battery storage system. Whilst there are a number of air turbine systems that could be employed with this invention a special dual turbine arrangement is described in the request specification.

SPECIFICATION
Air power for propulsion

CONTENTS

Section			Page
	INTRODUCTION		5
1		Summary of Current Energy Provision	
2		The Problem with Energy	
	PROJECT		
3		The Idea and Some of the Principles upon which the Idea is based	
	3.1	The Idea	10
	3.2	The Principles involved	
4		A more General Look at the Principles Involved	
5		Design Features	
	5.1	Car Body Design	
	5.1.1	General considerations	15
	5.1.2	Suggested Designs	
		A. Frontal Design	
		B. Rear Design	
	5.2	Turbine Design	
	5.2.1	Arrangement	20
	5.2.2	Primary Turbine	
	5.2.3	Secondary Turbine	
	5.3	Further Discussion on the Partial Vacuum Beneath the Car	
	5.4	Generator—Some Related Design Considerations	
	5.5	Battery System—Some Design Considerations	25
	5.6	Materials	
6		Verification of the Feasibility of the Idea by Calculation	
	6.1	Calculation to Determine the Amount of Energy Produced by the Turbine System	
	6.2	Calculation to Estimate the Drag Forces Acting upon the vehicle	
	6.3	Summary Table of the Results	30
	6.4	Further Discussions of the Results	
7		G.A. Drawing Notes	
8		Text Figure Diagrams	
9		General Arrangement Design Drawings	

3 The idea and some of the principles upon which the idea is based

3.1 The idea

The idea is a method to provide power for the propulsion of a road vehicle. The same principle could probably also be extended to include other forms of transport—for example, trains. However, this report deals solely with the principle as applied to a road vehicle.

Essentially the idea is to induce a high level of kinetic energy of motion into the localised air through which a vehicle is travelling and convert this kinetic energy by means of an air turbine into electrical energy, which would then be used to power the vehicle.

3.2 The principles involved

Air primarily comprises a mixture of gases, i.e. 79% Nitrogen, 20% Oxygen, 1% Carbon dioxide and two other important constituents water and dust particles. These latter two components provide sources for the storage of solar energy within our atmosphere, and approximately 19% of all the sun's energy which is transmitted to Earth is contained within the air surrounding the Planet. This solar energy gives rise to the kinetic energy of motion of the winds and waves, both of which can be harnessed to give wind and wave power. The atmospheric solar energy is also important in the hydrological cycle which gives rise to the gravitational energy of rivers, from which hydroelectricity is produced.

Air has a number of important properties and the idea is primarily dependent upon four of these as follows:

1) Air is structured in layers which enables it to have excellent shear flow properties.
2) On being caused to flow by some means or other, air has imparted to it kinetic energy of motion. In the case of a natural wind this flow is brought about by high and low pressure regions in the atmosphere which cause the air to flow from the high to the low pressures zones. Thus, the solar energy which went into the creation of these high and low pressure regions is converted into the kinetic energy of motion of the wind.
3) A relatively high velocity air stream undergoes very little compression when subjected to a restriction to flow, or a vertical plate at right angles to the direction of flow. In the former case

in order to compensate for a reduced flow space, there is a proportional increase in the velocity of an air stream flowing through the reduced region.

4) The sum of the dynamic pressure of an air stream, i.e. it's kinetic energy of motion, and the static local pressure of the air, are a constant, in accordance with Bernoulli's equation.

These four properties are all inter related and the idea is based around them. When a car travels forward through air it has somehow to forge a path through the air, and the displaced air passes around the car on all sides.

Consider two cases, as follows:

Car A—a car with a vertical front

Figure 1

A—Air passage associated with the Car

B—Large amount of turbulence in the wake of the car.

Car B—a highly streamlined car

Figure 2

A—Air passage associated with the car

B—Little turbulence in the wake of the car, and layered structuring is reconstituted fairly rapidly

In the case of Car A a large amount of the power being placed into the car will be expended in pushing aside the air and forging a pathway for itself. With the streamlined car, on the other hand, a comparatively small amount of the input energy is expended in forging a pathway through the air.

Therefore, for this latter car to travel at the same velocity as Car A, a much less input of energy would be required, given that they were of similar weights and had the same level of frictional forces to overcome.

When Car A impacts into the air, as illustrated, a large proportion of the car's own kinetic energy of motion is transferred to the air, and energy is expended in this manner. As a result, a high degree of air turbulence takes place around the car and at its rear, which creates drag forces on the car. With Car B a totally different effect takes place with respect to the air passage associated with the car. Here the car still has to forge a pathway for itself through the air passage, but, because of it's pointed front and streamlined body, it is an action to cleave the layered air and slip between the separated layers, pushing them apart, as the wedged shaped body passes through, with the creation of little air turbulence. Hence, compared with Car A, this car expends very littel energy in overcoming the resistance to forward motion presented to it by the air passage. Furthermore, as a result of this method of passing through the air passage, the air which is displaced by the volume of the car is caused to accelerate as it passes over the surfaces of the car body. This acceleration occurs because air does not compress at these velocities, but instead it accelerates around the car, thereby compensating for the loss in space in the air passage due to the volume of the car. The greater the volume of the displaced air, the more will be the acceleration of this air as it passes over the car body.

At the front of the car the air will have an effective air windspeed, in relation to the car, equal to the speed of the car, assuming the air passage to be comprised of still air. The velocity attained by the displaced air, in relation to the car, as it streams over the body of the car, will be something over and above this frontal relative air speed. The final air velocity achieved by this acceleration will depend on the efficiency with which the car's shape can cleave and streamline the air layers; the amount of the displaced air; the nature of the streamlining, i.e. whether the air streams are caused to undergo concentration. If this latter is the case, then higher velocities will result.

As with a natural wind, the streamline air as created in the above manner, will have a kinetic energy of motion. This kinetic energy is proportional to the square of the velocity of the air stream. Thus, because of this squared relationship, there is substantial energy advantage to be gained by concentrating the air streams and increasing their velocity in this way.

Thus, the basis of the idea is to produce a car with low air resistance, which induces a high degree of streamlining and has a fairly high displacement capacity, concentrate the air streams and then harness the kinetic energy of motion of this relatively high velocity air stream. In order to do this, an air turbine would be placed at right angles to the air stream at the point of highest air velocity, and the kinetic energy of motion of the air stream then converted into electrical energy. This would then be stored in batteries, which in turn would provide the power to propel the car by means of an electric motor.

The positioning and design of the turbine system would be such that it would itself have little overall effect on the resistance to forward motion of the car. On the contrary, it is hoped that some of the normal drag forces that are associated with a conventional car could be reduced by the incorporation of this turbine system.

The following illustrations are intended to diagramatically show some of the points which have been made. However, it should be borne in mind that these illustrations are not the final design of the car being proposed, but are given to illustrate certain of the many features and concepts involved.

The relationship between the velocity and local pressure is given by the Bernoulli's Equation:

$P + \frac{1}{2}\rho V^2 = \text{Constant}$

The expression $\frac{1}{2}\rho V^2$ is the dynamic pressure of the air and quantifies its kinetic energy of motion.

The highest velocity occurs at point B, i.e. in the narrowed section of the flow tube. Therefore in this region its dynamic pressure, or kinetic energy of motion, is at its highest. Accompanying this increase in dynamic pressure is a corresponding decrease in local pressure, viz,

Figure 8

Points A, B and C as on Figure 7.

a—Maximum dynamic pressure acting in the forward plane.

b—Minimum local pressure acting at right angles to forward plane.

At point C the air velocity is beginning to slow down as the tube broadens, resulting in a lowering of dynamic pressure and a corresponding increase in local pressure.

The sum of the dynamic pressure and the local pressure at all points—A, B and C—is always equal to the same constant, in accordance with the Bernoulli's Equation.

Bernoulli's principles as applied to aircraft flight

Inducing air flow and pressure differences in compliance with the Bernoulli's Equation is one of the main principles involved in aircraft flight.

Considering the profile of an aircraft wing as it travels through the air, viz,

Figure 9

A—At this point below the wing a decrease in the velocity of air flow takes place, resulting in a decrease in dynamic pressure but a corresponding increase in local pressure.

B—At this point above the wing an increase in the air flow velocity occurs causing an increase in dynamic pressure and a corresponding decrease in local pressure.

The splitting of the air layers in this way is known as streamlining the air.

Flying an aircraft makes use of the fact that a low local pressure is created above the wing and a relatively high local pressure is created below the wing. Thus, a lifting force acts upon the wing, with 'suction pressure' acting on the upper side of the wing and 'push pressure' acting on the underside of the wing.

Another important effect in the streamlining of the air is that a boundary layer of air is formed on the surface of the streamlining object that is travelling through the air, forming a stationary skin of air on the surface of the object. This acts as a boundary between the object and moving air flow. As the air layers get further away from the surface of the object, then their velocities increase. As long as this surface skin of air remains intact then there are virtually no drag froces holding back the wing. However, if the surface layer of air breaks away from the wing, which it can easily do if the angle of attack is not correct, then drag forces are created.

The problem with aircraft flight is to optimise the angle of attack to give maximum lift forces and minimum drag forces. This is a very critical and sensitive angle and it is of the order of 4° inclination in relation to the horizontal plane.

Although there is this stationary skin of air on the surface of the object, the full air velocity is reached not too far off the surface of the object, i.e. within a fraction of an inch.

In aircraft flight little use is made of the kinetic energy of motion that is created by the increased velocity of air flow, i.e. of the dynamic air pressure created by the wings. However, by considering air flight, it is easy to see the potential energy that is contained in the kinetic energy of motion, since this pressure energy increases by an amount effectively equal to the lifting capacity of the lowered local pressure, in accordance with the Bernoulli's Equation.

The kinetic energy of motion of the air stream can potentially all be converted into pressure energy on striking a vertical plate placed in the path of the air stream. The total force acting upon the plate is equal to $\frac{1}{2}\rho v^2$ x area of the plate. Therefore this represents a potential source of energy and can be harnessed by placing a turbine in the path of the air stream and converting the rotatory motion of the turbine into electrical energy by means of an electrical generator, in a similar manner to wind electrical generation.

This, therefore, is the energy source on which the idea depends, as discussed in Section 3.

At first sight, because there is no apparent external addition of energy (hopefully), such a method of propulsion may appear to be the allusive perpetual motion that Man has strived to achieve. Indeed in the original concept of perpetual motion this type of propulsion may in fact meet all the necessary criteria used for the definition of perpetual motion. However, there is, of course, a very definite source of energy, this being the kinetic energy of the air streams passing over the car body induced by the shape and speed of the car. This can be regarded as the Primary Energy Source. The end use energy is the electrical energy which is produced from the kinetic energy, a process which is carried out on the spot whilst the vehicle is travelling forward, and, indeed, a process which is dependent upon the forward motion of the car. The functional energy is the amount of electrical energy actually used in propelling the vehicle.

Thus, what in fact is happening within the energy cycle is a reduction to a zero [illegible]

111

To put it another way, the functional energy is used roughly in the proportion of 50:50, for overcoming air resistance: other energy usages, air resistance being the main factor in the 20% fraction above.

As can be seen from this breakdown, the petrol engine is a very inefficient system for propulsion with 65% of the end use input energy being wasted as unusable heat energy. In the car being proposed this is obviously not the case and there is little wastage of energy due to heat.

However, this car has to overcome similar forces to the conventional car, and therefore one might expect 50% of the input energy to be used up in overcoming the air resistance to forward motion and 50% for the other power requirements, the same as for a conventional car's functional energy usage.

Just to consider the energy being produced by the turbine car in relation to the energy being consumed by the car—Like other cars, maximum energy consumption will occur during acceleration or when climbing a steep gradient, whilst at a cruising speed, or going down an incline, energy consumption would be substantially lower. Under these latter two conditions, the acquired momentum energy of the vehicle would contribute enormously to the maintenance of speed. Thus, power consumption may be say 50 HP during acceleration or when climbing, and only about 20 HP when going down a hill.

The energy being produced by the air turbine, on the other hand, would be occurring in the opposite manner. Peak production would take place during cruising speeds. This would take advantage of the acquired momentum energy of the vehicle, whilst the energy which is produced going down a hill can in a way be regarded as bonus gravitational energy being placed into the energy production system via conversion into momentum energy of the car. Thus, one of the principles of the idea is that the excess energy that would be produced at cruising speeds would be stored in batteries for use during say acceleration when energy consumption would probably be more than the system was producing. The overall effect would become equalised over the full length of a journey. This aspect is dealt with further in Section 6, in relation to the results of the calculations.

A point that can be appreciated at this stage, however, is that the weight is an important factor, not only in relation to the power requirements needed to overcome the gravitational pull on the car, this being of a negative nature, but also on the positive side of the energy balance in relation to the momentum energy attainable by the car.

Therefore, occupants of the car become an integral part of the energy cycle, contributing to the over-supply of energy during cruising, and contributing to the over-usage of energy during say an acceleration move. Hopefully, over the full length of the journey these will cancel each other out and the occupants will have travelled on their journey for free in terms of energy usage.

An important factor in the system being proposed is the efficiency with which the kinetic energy of a high velocity stream of air can be transferred and transformed into a turbine rotation.

The kinetic energy of any moving body is represented by the following equation:

$$E = \frac{1}{2} mV^2,$$

as derived by Newton

where m=mass, and V=velocity

In the system that we are considering, the mass, m in the above equation has been replaced by ρ, the density of air, and thus we obtain the dynamic pressure half of the Bernoulli's equation as

$$KE = \frac{1}{2}\rho V^2$$

This represents the dynamic pressure (or the kinetic energy) of the moving air stream per unit area.

Therefore, the total pressure force due to the air stream acting upon the impellers of the turbine will be equal to: $\frac{1}{2}\rho V^2$, multiplied by the cross-sectional area of the impact zone.

On impact, several things can happen to the kinetic energy contained within the air stream, and not all of it will be converted into electrical energy. The laws of Newton tell us that the total sum of the energies after a collision are equal to the sum of the energies before the collision. On impact at one extreme, and in the ideal case, all the air molecules will come totally to rest and transfer all of their kinetic energy to the impellers of the turbine where it would all be converted into rotatory energy. It can be derived from the Laws of Newton that the sum of the squares of the velocities before a collision is equal to the sum of the squares of the velocities after a collision in compliance with the laws of conservation of energy.

Thus, if the collision was totally an elastic one, then the impellers of the turbine would acquire a rotation energy equivalent to the energy of the air stream in accordance with the above mentioned principle and the air stream would maintain velocity.

However, all of the kinetic energy of motion of the air stream will not be converted into the theoretical rotation velocity.

Firstly, it is not an elastic collision, but with [illegible] this stage, the [illegible] of the [illegible] will

intermediary steps in going from primary to functional energy, with the benefits of economy and efficiency ensuing.

Considering similar diagrams to those given in the previous section, as follows:

Figure 10

A—The car's air passage.

B—A car with a vertical front, travelling forward through it's air passage.

Here the kinetic energy of motion of the car is used up in pushing aside the air molecules and energy passes from the vehicle to the air, in accordance with Newton's Laws concerning conservation of energy.

Figure 11

A—Low pressure boundary layer on the surface of the car.

B—High forward dynamic pressure of the air stream flow over the car.

C—Air Turbine Electrical Generation System.

D—Emission of used air, effective in lowering the rear drag forces.

E—Electrical Energy.

F—Electrical Propulsion.

In the case of the car, its streamlining has caused the air to split into two separate components, in accordance with the Bernoulli's Equation: $P + \frac{1}{2}\rho V^2 = \text{Constant}$. These are:

(a) A low local pressure, P in the above equation, on the surfaces of the car over which the air is streaming, enabling the car to travel much more freely through the air, and without the need to expend large amounts of energy in pushing the air.

(b) A corresponding high dynamic pressure streaming over the car towards the air turbine, represented by $\frac{1}{2}\rho V^2$ in the above equation, the energy of which is then converted into electrical energy to be used for further propulsion of the vehicle.

Thus, with the streamlined car, less energy is expended in passing through the air in comparison to the first car, and the air which would have caused this energy to be expended, instead, is caused to give energy to the vehicle for its propulsion. This air then goes on to reduce rear drag forces in comparision with the previous car.

Thus, in the case of the streamlined car, there is an overall threefold improvement in the energy input/output balance in relation to the first car.

An important aspect of this process is the effectiveness with which drag forces can be minimised, not only due to the body of the car, but also due to the turbine system. This is dealt with in various places following.

The power required to propel a car forward has to overcome several drains on that power, as follows:

1) The air resistance of the vehicle, i.e. the energy which is expended in forging a pathway through the air passage, and this—the air resistance of a vehicle—is comprised of two main components:

(a) Form drag

This is the energy required to move aside the air molecules through which the car is travelling, due to the form of the car, i.e. due to its shape and size;

(b) Frictional drag

This is the energy required to overcome car body surface to air frictional forces. The smoother the surface, the lower the frictional drag

2) The mechanical frictional forces

It is worth commenting here that the mechanical frictional forces of the turbine generating system in the car being proposed are separate from the mechanical drive frictional forces which the electric motor propulsion system has to overcome.

3) Tyre to road frictional forces

Having put sufficient energy into the propulsion system to overcome the above forces, then whatever energy is remaining is available for acceleration of the car to the desired speed and then for maintaining that speed. In a car powered by petrol the breakdown of the input end use energy is approximately as follows, for a normal saloon car:

Total end use energy
- 65% — wasted heat energy
- 20% — used in overcoming air resistance and the mechanical frictional forces

Functional energy
- 15% — used for overcoming tyre to road forces, acceleration and maintaining speed

be the principle factor here which will place a restraint on rotation, and then there are the mechanical friction forces of the system to overcome.

Secondly some of the energy on impact will probably be converted into heat energy.

Thirdly, not all the air molecules in the air stream will pass on their kinetic energy of motion at the turbine impeller interface. For reasons discussed later, it is proposed that a dual turbine system is used, having a primary and secondary turbine in the path of the air stream. Just one of the benefits of this system could be that energy not captures at the primary stage would have a second chance of being passed on at the secondary turbine stage.

Another important factor upon which the success of the car will depend is the level to which the air stream can firstly be accelerated to, and then maintained, by the shape and streamlined nature of the car body.

Among other things this is dealt with fully in the next section, but a principle feature is the application of suctional forces at the exit to the turbine system, some of which are an inherent feature of any car and others which are created through special design features.

5 Design features

General arrangement diagrams of the design discussed in this section are given in the final section of this report—Section 7

5.1 Car body design

5.1.1 General considerations

The design of the car body is obviously probably the most important single aspect of this idea, since the whole success of the idea depends on how well one is able to streamline the air and induce and sustain an increased level of kinetic energy of motion into the air stream purely by means of the body, design.

The basis of the problem is to create a shape which causes a maximised displacement of air, with a minimised level of drag forces acting negatively upon the car, whilst channeling, accelerating and concentrating as much of the displaced air as possible into one small region where its kinetic energy can be harnessed again with as little effect on negative drag as possible. Drag is the resistance presented by the air to the forward movement of a vehicle moving through it and in general this is the summation of two components:

(i) **Form drag** - the energy expended in pushing the air on one side;

(ii) **Friction drag** - the resistance created between the car body and the layers of air moving over the body. (previously discussed in Section 4, page 22).

Since this method of propulsion will depend on maximum use being made of air streamlining designs, form drag will be at its minimum limit and friction drag will perhaps be a more important consideration of these two components. The friction drag will be proportional to the amount of car body surface area that the air is adjacent to. The more the air displacement, the more the surface area and the more the potential for frictional drag forces. On the one hand, air displacement is required, on the other hand, frictional drag forces want to be minimised.

Much can be done to lower frictional drag by attention to car body surface finish, and this is dealt with more fully in Section 5, in the discussion on materials. There it is suggested that High Impact Resistance glass would be an ideal material to help to overcome frictional drag. This material has an extremely high degree of surface smoothness, and its ability to maintain an intact boundary layer of air would be very high. Maintenance of the boundary layer is the main factor in overcoming frictional drag, with of the order of manifold improvements possible if the boundary layer can be kept totally intact. It is like creating a stationary fine cushion of air on the surface of the car body and in this way separating the surface from the adjacent moving layers of air.

It is of interest to make the point here that one way of demonstrating a truly elastic collison (a discussed in Section 4) is to overcome the frictional forces involved by placing the objects on a cushion of air. This therefore gives one an appreciation of how effective a cushion of air is in overcoming frictional forces, with air to solid forces becoming negligible in respect of friction.

In designing the body of this car, in order to separate, streamline and accelerate the air layers, there are several important effects to be aware of:

(a) The tear drop shape

This is the shape which parts the layers of air the best with the minimum of resistance by the air, for an optimum appreciable volume of displaced air. In other words it is the optimum shape for displacing the most air with the minimum amount of air drag. The shape has a length to breadth ratio of about 3.1 and its streamlining effect is as illustrated on Figure 12.

Figure 12

A - Forward moving, non-streamlined, tear drop shaped, object.

B - Air passage associated with streamlined object

Such a shape can have a drag coefficient as low as 0.05 compared with about 0.5 for a normal car shape.

(b) The Venturi effect

This has previously been discussed in Section 4.

It is a shape which was originally designed in order to cause an acceleration of air through a tube, principally in order to make use of the localised low pressure for the suction of some other substance into the tube. For this purpose its shape is extremely critical for creating the correct level of low pressure. This shape is as shown on Figure 7, given in Section 4.

As described fully in Section 4, the relationship between the velocity and local pressure is given by the Bernoulli's equation:

$$P+\tfrac{1}{2}\rho V^2=\text{Constant}$$

Just to summarise the effects taking place as the air passes through the Venturi tube—

A—Velocity increasing—dynamic pressure increasing, i.e., $\tfrac{1}{2}\rho V^2$; local pressure decreasing, i.e., p.

B—High speed velocity—high dynamic pressure; low local pressure.

C—Velocity decreasing, dynamic pressure decreasing, local pressure increasing.

The term 'Venturi Effect' has now been extended to describe almost any set of conditions where an acceleration of air and a lowering of local pressure is brought about in air by shapes similar to that of the Venturi tube.

In this respect it is interesting to make the comparison that the Venturi tube's cross-sectional shape is very similar to that of the cross-section of two adjacent, opposite halves of a tear drop shape, with air passing between them. In recent years it has become a commonly used term to describe the effect due to shapes beneath a car which give rise to lowering of pressure through air acceleration. This effect is illustrated on Figure 13.

Figure 13

A—Nose of car travelling forward.

B—Air passage.

C—Road surface.

D—Venturi effect occurring in the narrow section between the road surface and base of nose, creating an acceleration of the air flow and a lowering of local pressure, which helps in its road holding.

(c) Lift and drag effects

These effects have been described to some extent in Section 4 in relation to a wing profile.

One of the more important aspects in relation to a car body is to try to create shapes which will keep the boundary layer intact, thereby cutting down drag forces.

Figure 14 illustrates the breaking away of a boundary layer on a typical shape, resulting in the creation of form drag forces.

C—Transition point.

D—Tnicker turbulent layer, creating negative drag forces acting upon the surface towards the rear.

There are a number of problem areas on a car where form drag can be created and 15, a fairly streamlined car, highlights these regions:

This illustration shows a vehicle moving forward through air, separating and displacing air resulting in an acceleration of the air stream over the surface of the car body.

At the front of the car, in region A, separation of the air layers has not taken place too smoothly and a turbulent region is created, giving a higher resistance to forward motion. With a sharper front, a smoother separation would have taken place and the form drag in this region would have been reduced.

At B, in the windscreen region, the boundary layer has separated from the body, and a turbulent region is again created, causing another zone of increased air resistance.

At C, the boundary layer again breaks away from the surface, but unlike the previous regions A and B, which are both areas of increased pressure pushing on the car, this is a region where the pressure is lower in comparison, resulting in a holding back force acting on the car.

D indicates drag froces due to the wheels and the shape of the underside of the car, which tend to act to hold down the car.

The regions such as E, where the boundary has remained intact, have the least resistace to forward movement, and here the increase in air velocity is approaching its highest level. A lift force is also created due to the local low pressure of the boundary layer.

This lift force can be a serious disadvantage since it tends to lift the car off the road and thereby impair road holding and create instability.

The latest designs of cars which are trying to achieve low drag coefficients through streamlined

have to try to optimise between lift and drag forces. Drag forces can be put to good use by causing them to act on the underside of the car, as described earlier. Thus these can counteract lift forces on the upper surfaces and give better road holding.

Another way to counteract lift effect is by an appropriate distribution of weight. In a conventional car this can sometimes prove a little difficult, since the internal components of the car have, more often than not, to be in a predetermined position. The car that I am proposing is more versatile in this respect since its heaviest component, the battery storage system, can be split up and distributed around the car in the best positions to counteract regions of increased lift forces, all connected by appropriate wiring.

5.1.2 Suggested designs

Arriving at the best car body design for the car being proposed is something which will ultimately have to be determined through trial and error experimentation, and for this, initial experiments with models in a wind tunnel would probably be advantageous from the point of view of keeping down development costs.

At this stage it is a question of applying oneself to the problem theoretically, bearing in mind all the various effects known to be possible from past experience. My initial designs did not particulary set out to make good use of the suctional drag forces at the rear of the vehicle, although even in those early designs these drag forces would have helped quite considerably.

As previously mentioned, some of these earlier designs are included in the Drawing Section, and these are Designs 4—9.

The later designs for the car, Designs 1, 2 and 3, attempt to make maximum use of the possible suctional forces that can be created at the rear.

In addition to this development, the frontal design and approaches to the turbine unit have also been developed further, and I intend to first explain these aspects in relation to Designs, 1, 2 and 3.

(a) Frontal design

Obviously the turbine system one chooses will have a large bearing on the body design, and again experimentation will ultimately be necessary to determine the best turbine design and system for the car. I explain more fully possible turbine systems in the next section (5.2). However, for the car design being proposed, at this stage, I have chosen a dual turbine system, comprising a primary and secondary unit which are interconnected. In Design 3, both of these are Radial Flow turbines as illustrated in the drawing.

Designs 1 and 2, on the other hand, employ Axial Flow Turbines. These systems are fully explained in the next section dealing with turbines.

Considering Design 3, the frontal design of the car has first to achieve separation of the air layers as smoothly as possible, then cause the displaced air to flow unimpeded over the surface of the vehicle, during which concentration and acceleration of the air streams has to take place, with the car body itself having as little resistance to forward motion as possible.

Thus for the basic body shape I have used the upper half of a tear drop shape with a length to breadth ratio of approximately 2:1 for the full tear shape.

At the tear drop's broadest point I have then created a Venturi shaped entry into the final air stream tunnel leading up to the turbines, in conjunction with an upper Unit, as illustrated.

The idea behind this design is to create an entry into the air stream tunnel, which theoretically would give a higher velocity at this early stage in the formation of the narrowed air stream than the theoretical air speed directly at the point of entry to the turbine. Theoretical air stream velocity is simply a function of cross sectional area with velocity being inversely proportional to cross-sectional area.

Thus, by this means, it is hoped that one could help to counteract any slowing down of the air stream due to a back pressure building up because of turbine rotation restraint, resulting from the build up of the back EMF of the generator. In other words, to try to maintain the power source, the induced high velocity air stream as close as possible to the theoretical maximum velocity. To further assist in this respect, a number of thin tear drop profiles, positioned across the full width of the air tunnel, have been situated in the air stream, as indicated.

It is hoped these would function as follows:

After the Venturi entry, the air tunnel is allowed to increase slightly in size, which will have a slowing down effect on the air stream, but then two of the tear drop profiles have been placed in the air stream parallel and equidistant apart, in order to accelerate the air stream back up to the Venturi entry speed. On passing these profiles the speed will again start to slow down, but then the same process is repeated with a further set of the tear drop profiles, which will raise the speed of the air flow again just prior to entry into the turbine system.

In addition to this repeated speeding up process, the profiles should also function as a kind of a one way valve system. If one considers the equilibrium balance between air flowing in and air flowing outwards, the in-flowing air would establish its maximum velocity, as it goes by the profiles, much quicker than the air flowing outwards, and therefore the in-flowing air should overcome and shift the equilibrium speed of the further towards maximum.

Thus, the Venturi entry and the tunnel should become a buffer zone in which the steady state equilibrium velocity of the air stream is maintained closer towards its theoretical maximum.

Consider the diagram as shown of Figure 16.

As the air stream approaches the turbine its velocity increases as the air space gradually reduces with velocity going from A at the start to B at the turbine entry based on a theoretical assessment of speed.

In actual practice, the air flow will arrive at a steady state equilibrialised velocity somewhere between A and B, say with a value equivalent to C. Using techniques as described above, one would hope to get the equilibrialised velocity, C, closer to B than it would otherwise have been in the absence of such design features.

A precedent for the principle being put forward in respect of acquiring power by a moving body from the air of an air passage, is the Ram Jet Rocket. This Rocket has a propulsion system, which is very much reliant on its forward speed to produce what is termed a 'Ram effect', in order to collect and pressurise the air of the air passage through which it is travelling. This air is then used in the production of forward thrust by a special process of emission at the rear of the rocket, in conjunction with fuel injection and combustion.

A number of the principles involved are also present in hydro-electrical generation when a Pelton Wheel Turbine is employed. This process relies more on an induced pressurised water jet rather than simply a particular flow rate of water. Thus, for the same flow rate, a higher electrical output can be used if the water is induced, by restriction at its outlet, to have impingement velocity pressure as well as the static pressure of the basic head of water.

Such principles would particularly apply in some of the designs where it is suggested that small restricting vanes are placed in the air stream right at the point of entry to the turbine system in order to accelerate the air in the final stages.

Parallel principles are also present in the method proposed for accelerating the air in the air wind tunnel by means of the horizontal tear drop profiles.

It may also be beneficial to use tear drop profiles across the front of the car before entry into the Venturi, in order to help direct, concentrate and consolidate the air streams as they approach the Venturi, in a similar manner to the way water flow is directed sometimes in hydro-electrical generation Finally, as mentioned, in some of the Designs I have placed a row of very small profiles directly on entry into the turbines. These are to more sensitively direct the flow of air as it impinges onto the turbine impellers, as well as to accelerate the air in the final stage. This aspect is dealt with more fully in the later section which deals with turbine.

(b) Rear design, considering Designs 1, 2 and 3.

Apart from all of the frontal design features and all of those connected with the turbine design possibly the main other single feature that will aid the efficiency of energy conversion will be the exertion of rear suctional forces acting upon the exit to the turbine system.

Some of these forces are inherently present with any vehicle due to the suction force created in the rear slip stream. It is also intended to create additional suction, and it is hoped that the combined effect would be to ensure that the air stream velocity would be maintained very close to its theoretical maximum, and thereby the level of energy present in the air stream available for conversion into turbine rotational energy.

Firstly, it is intended to create a partial vacuum beneath the car by scooping the air away at the front of the car with a kind of a 'snow plough' device, as illustrated. The air removed by this action will form a part of that being directed towards the Venturi.

By removal of air at the front, very close to the ground, a fairly high level of partial vacuum will be created beneath the car. This is very much the same principle as the 'Skirt' idea that has been introduced recently into motor racing in order to give better road holding. This will be an added benefit in the car under consideration and will help to counteract the lift forces on the upper surfaces of the car due to the high degree of streamlining.

The effect of this partial vacuum will be to aid the extraction of air from the turbine system by its application at the rear most exit, where it will join forces with the rear slip stream suctional drag forces.

I have also included ducting arrangements in Designs 1, 2 and 3 (at this stage) between the turbine inter-zone and the underside of the car, in order to assist in the removal of air and to maximise the pressure difference across the primary turbine. In Design 1 and 2, as a further suctional aid to assist in the extraction of air from the inter-zone, I have incorporated a Venturi suction method in the upper surface of the car, using a ducting arrangement as illustrated.

All of these processes operate in conjunction with the interaction between the primary and secondary turbines and are discussed in more detail later, in the following section dealing with the Turbine System.

The frontal scoop being so close to the ground may cause problems if there are bumps in the roadway. For this reason, it is therefore suggested that this unit should be a separate fixture made of an appropriate narrow gauge light material which can be lifted at the press of a button, via a hydraulic mechanism, to a point where it becomes level to the rest of the car's underside. For most driving, with

the good condition of our road network, there would be no problem, but there would inevitably be occasions when an unexpected obstacle appeared in front of the car and quick operating retraction mechanism would be required. Obviously it would be ideal if this operated by means of an automatic sensing device.

The rear shaping of the car will have a large influence on how much of the slip stream drag forces can be applied in the region of the turbine exit, and it may be that the designs illustrated would not be the best in this respect. One may be able to create improvements with off-body aerofoils. Experimentation would really be required to determine this aspect of the design.

These suctional forces are created because the air within these regions has been depleted. By allowing the suction forces to act upon the exit to the turbine unit, the depleted zones of air will be re-charged with the air passing through the turbine system, and as a result of this, the overall negative drag forces acting upon the rear of the car body should be reduced. In a normal car these drag forces are a major contributory factor to the overall air resistance of a car. Because of this immediate replenishment of air in the rear slip stream void zone, and because of the high streamlined nature of the car body at the front, it is considered likely that the overall drag coefficient of the car being proposed could be somewhat less than a conventional car.

A similar principle is used to cut down drag forces in specially designed wings, which have a slot incorporated into them to allow air to pass through from the underside high pressure region to the upper, lower pressure, surface of the wing, where drag would otherwise be taking place due to the boundary layer breaking away.

Also, a similar idea is applied to another type of wing which is pressurised with air inside the wing, and this air is allowed to flow out through a slot on the upper surface of the wing to reduce the effect of drag caused by the breaking away of the boundary layer.

As mentioned previously, some use of aerofoil air deflectors set off the car body may be useful in helping to create and concentrate the suctional forces in the region of the ducts, and a further use for these would be to direct the air being emitted, so that maximum use is made of it to reduce the drag forces acting elsewhere upon the rear of the car body.

A final body design feature to mention at this stage is the slight upturn in the lower surface of the air stream tunnel at the point of entry to the primary turbine. This will help to direct the air upwards and impinge on the underside of the impellers, and it will also cause air stream acceleration in the last few stages before impact – as, of course, will the row of small air stream directors. This will assist in increasing the level of kinetic energy imparted from the air stream to the impellers, and it may be that features such as this will create as much advantage as is gained by the induced pressurised water jets of a Pelton wheel hydro-turbine, for example.

5.2 Turbine design

5.2.1 Arrangement considerations

It is a little difficult to know at this stage which type of turbine system, both in terms of design and arrangement, would give the most efficient energy conversion in the car being proposed.

In all of may designs so far I have opted for a dual turbine system and the advantages which I think may be gained from this type of arrangement are discussed below, and also later on in the section which deals specifically with the secondary turbine.

However, it may be found in practice that just a single turbine unit would be adequate.

In the dual system the principle idea would be to arrange for the secondary turbine to rotate faster than the primary by means of an appropriate interconnecting gearing ratio between the two turbines, and in this way arrange for the secondary turbine to have a higher air displacement capacity than the volume of air entering the primary turbine. The main advantages thought to be gained by this dual arrangement are as follows (discussed in relation to Design 3, which uses Radial flow turbines at both stages):

1) The more rapidly rotating secondary turbine will quickly transfer the air, after collision with the impellers, to the rear of the vehicle, and this will minimise any tendency for a pressure to build up, which would otherwise result in a slowing down of the air stream velocity.
2) This rapid displacement of air to the rear of the vehicle will more readily allow the depleted zone in the wake of the car to be replenished, thereby reducing drag forces better, which would otherwise be acting upon the car body at the rear.

One can see here the way in which the car's slip stream drag forces aid the car when they are allowed to act upon the impellers of the turbine, since the impellers can respond to the applied force, and thus their rotation is assisted, resulting in improved turbine efficiency; whereas these same drag forces acting upon a solid car body surface will, instead, just have the effect of increasing the car's overall air resistance to forward motion.

3) The rapid displacement of air from the region between the two turbines will create a higher pressure difference across the primary turbine than would otherwise have existed, and this will allow the air to flow faster through the primary turbine, thereby maintaining a higher level of kinetic energy. This low pressure could also exert a downward pulling force on the impellers of the primary turbine in the first quarter of its revolution.

4) One of the main principles of this dual turbine system is that it would be hoped that the interaction between the two turbine units, as described in 1) and 3) above would create a self-sustaining action.

The primary turbine would first cause rotation of the secndary turbine, then the secondary turbine would, in turn, assist the rotation of the primary turbine in the way described, and so on, mutually assisting each other's rotation.

5) Another possible function for the secondary turbine, particularly in the case of Design 3 would be for it to capture the energy of the air stream that was not given up at the primary turbine stage. However, because the secondary unit is rotating at more revolutions per unit time than the primary turbine, capturing any energy of the air stream that managed to get by the primary turbine would more likely occur if this air, which would probably be mostly at the periphery, struck the impellers of the secondary unit in the central region of this turbine.

This is because the speeds at these respective points would be such that the air stream would be more likely to have a higher velocity than the angular velocity of the secondary turbine in its slowest central region. This, in fact, is probably what is more likely to happen, rather than vice versa, when little energy would be expected to be transferred.

Optimising for this effect would be one of the things to consider when positioning the turbines in relation to each other, and also when selecting a design for the impellers of the secondary unit.

Thus, these are some of the main principles involved in the dual turbine system, which it is believed would give rise to better overall efficiency in energy conversion over just a single primary turbine.

To a certain extent the idea is similar to that used in a Jet engine, but with the action working in the opposite direction.

The relative speeds of the primary and secondary turbines will probably be fairly critical with optimum conditions probably changing with changing car speed.

Continuing the discussion in relation to Design 3:

The pulling force, due to the low pressure region between the turbines acting upon the primary turbine, as described in 3) above, could also exert a negative influence in the second quarter of the turbine's rotation by causing retardation after the impellers have rotated past the low pressure inter connecting region.

Therefore, in order to try to overcome this negative influence to rotation, a duct has been incorporated, connecting the partial vacuum beneath the car to a region lower down the primary turbine's rotation, in order to further extend the region of the downward pulling force. However, on passing through this duct region, a negative drag would again probably be exerted, but this arrangement is very much more flexible, in that it contains a number of variables, all of which can be slightly and sensitively altered. Therefore, it should be a fairly straightforward matter to find the optimum conditions which give the greatest advantage to the clockwise rotation of the primary turbine. It would be hoped that most of these variables could be altered during driving in order to be able to set optimum conditions for a particular driving speed. Obviously it would be better if these alterations could occur automatically with changing car speed.

The two principal variables would be:

1) the relative speed ratio between the two turbines, and 2) the pulling force due to the partial vacuum beneath the car acting upon the downward stroke of the primary turbine by means of the ducting arrangement.

This latter variable could be sensitively altered by means of a sliding cover over the duct. It may be possible to achieve this automatically using a similar mechanism to an automatic choke.

Likewise, it may be possible to automatically change the relative speed ratio using an infinitely variable gearing system operating between the two turbines.

Obviously, it would require quite a lot of experimentation, at different speeds, to determine the optimum settings for the different variables involved.

Among the most recent innovations in cars are the computer devices which electronically control fuel injection in response to accelerator pedal changes. This does away with all the usual inter-connecting linkages and more accurately controls the fuel input, giving an increase in fuel efficiency.

Thus, it may be possible to use similar devices for the two variables mentioned above, whereby one could include a computer which transmitted pre-programmed settings electronically to the variable mechanisms, in response to the speed of the car, these being continually monitored on the input side of the computer.

As previously mentioned, on the other side of the optimum balance for the relative speed ratio is the fact that if the secondary turbine was rotating too fast in relation to the primary turbine, then it would not be able to acquire any of the kinetic energy of the air stream which manages to escape at the primary turbine stage, and this would be another factor to consider.

The principal region for the application of the partial vacuum beneath the car is acting upon the main exit to the turbine system, where it joins forces with the rear slip stream drag forces.

Together these should exert an appreciable force, drawing the air through the system. This air

displaced immediately at the rear of the car where it will reduce the rear drag forces acting upon the car body at the rear.

Design trials would really be required in order to maximise concentration of the drawing force upon the turbine outlet and also to maximise the effectiveness of the expelled air in reducing the rear drag forces, as mentioned previously.

Another advantage of the dual turbine is that the drag forces acting upon the secondary turbine, with this type of air expulsion, should not contain any negative elements. One would not expect a negative influence on the underside of the impellers as they rotate upwards, since the abundance of air being issued should more than nullify any drag at this point.

However, if the secondary turbine was not present and the primary turbine was fully exposed to the drag forces then one would have fairly uncontrollable negative elements within the drag force reducing the overall net benefits of the suctional forces.

As already mentioned, however, rapid depletion of air between the two turbines could create negative drag acting upon the primary turbines.

This would obviously be eliminated if the air displacement ratio of the two turbines was 1:1.

However, under these conditions, because of the reduced air flow rate, one might start to get negative drag acting upon the secondary turbine.

Thus, when optimising the two relative speeds, one would be looking for this type of effect.

Under conditions of a 1:1 air displacement ratio, one would lose the advantages of the self-sustaining action, and this therefore would be another factor to bear in mind when optimising the speed ratio of the turbines.

It is, of course, very important to be aware of all of the various elements involved in this principle in order to be able to also make more accurate design adjustments when experimenting for the optimum basic design.

With just one single primary turbine the maximum drawing force that can be applied to the system is purely determined by the maximum force that can be obtained from external drag forces and the partial vacuum beneath the car. However, with the Dual System this is not just the case, and it would be hoped that appreciable advantage could be gained by having the secondary turbine displacing air at a speed fairly well in excess of the speed of air entry into the system. Under these conditions the drawing power being exerted across the primary turbine would be greater than could be obtained from the external forces, and, in addition to this, under such conditions, the external drag forces would be more effectively reduced by the air that was being issued out at the rear.

This really is the main principle behind the Dual System, and therefore just to elucidate a little more.

Under conditions when the air displacement capacity after the primary turbine stage is greater than the maximum theoretical air input to the turbine, one would be more likely to maintain the maximum theoretical air velocity, and also one would be more likely to be satisfying the depleted air zone in the slip stream of the car which gives rise to rear drag forces.

The turbine system may have to do more work under these conditions in order to displace the air, but the nett energy obtained would be more likely to approach the maximum attainable from the application of the rear drag forces. In addition, the energy savings in reducing rear drag forces would be more likely to approach the maximum—in relation to a system which just employed a single primary turbine, exposed at the rear, and taking what advantage it could of the rear drag forces, in a fairly uncontrollable and 'hit and miss' manner.

However, on the debit side, one may be increasing the negative element acting upon the primary turbine to a more significant level as air displacement capacity increases, even with the ducting arrangement to minimise this effect. This aspect makes a possible case for adopting circular types of primary turbines, and I discuss this later. However, with this latter type, the overall effect may be to lose more energy in the forward vector, because one would have to optimise between pitch angle and retardation of air stream velocity.

In Design 3 an alternative for the dual turbine arrangement could be as illustrated on Figure 17, (at this stage not particularly, considering impeller design). The advantage of this design over the arrangement, as given in Design 3, is that one may be applying the available drag forces to a greater extent. However, the negative component may also be higher and less controllable, which could result in the system being as good as that illustrated in Design 3, on balance. The main areas for this negative component are indicated by 1 and 2 on the drawing.

It is thought at this stage that Radial flow turbine designs, like the ones illustrated in Design 3, would have some advantages over Axial flow turbines in terms of:

(i) a smoother passage of air and less air turbulence resulting in less wastage of energy;

(ii) allowing more in terms of design refinement, which could extract more energy from the air stream;

(iii) less energy wastage in vector components.

However, the negative drag aspect may override any of these benefits and rule them out for this application.

This negative element could largely be eliminated by using circular turbine designs, since their

design is such that they operate fully exposed to the air stream forces, with all the forces being exerted similarly, no matter where they are applied to the turbine impellers.

Therefore, Designs One and Two are being put forward at this stage as possibly being better than Design Three. However, this could very well not be the case for the aforementioned reasons.

Both Designs 1 and 2 use Axial Flow turbines at the primary stage, and here, for both of these designs, the intention would be to use two identical turbine units standing side by side in the path of the air stream, in order to have the advantages of a full width air stream, as pre-determined and allowed by car size and shape. Whilst there are many possible designs for the impellers of this type of turbine, some of which are described later, it is thought that possibly a bladed aero propeller design would be the best from the aspect of efficient extraction of the air stream's kinetic energy of motion. Thus, this is the type provisionally being suggested for use in Designs 1 and 2, although this is open to further ideas at this stage.

Design 1 also employs an Axial Flow turbine at the secondary stage.

Design 2, on the other hand, employs a Radial Flow turbine at the secondary stage. It is though that this would have the advantage of displacing the air to the rear of the vehicle in a smoother, less turbulent manner, with the consequence of minimising the work done in the displacement of the air, and also probably causing the air to be more effective in reducing the rear drag forces. With both these arrangements, one would again try to create the self-sustaining action by having the secondary turbine rotating fast enough to give a higher air displacement capacity than the volume of air entering the system.

In order to assist further in Designs 1 and 2 for formoval of the air, suction ducts have been incorporated into the design, both functioning to such air out of the interconnecting zone between the two turbines. One is connected to the partial vacuum beneath the car. The other is a ducting connected to the top surface of the car body to a position where a Venturi shape has been incorporated. The action of the air accelerating as its streams over this Venturi shape will cause a very low local pressure, which in turn will draw air through from the interconnecting zone. It is thought that the inclusion of this Venturi shape will add very little to the overall air resistance of the vehicle, in comparison to the extra drawing power that itwould exert across the primary turbines, since the very fact that it works at all depends on the boundary layer remaining intact. Under these latter conditions, there is very little air resistance and it is only in regions of air turbulence where air resistance is created to any great extent.

Thus, in this design there are three features assisting in the removal of air from the inter-turbine zone—all of which could be indpendently varied in order to give optimum conditions for a given driving speed, using similar techniques to the ways discussed previously.

The principal concept with the dual arrangement is that one is trying to remove air from the inter turbine zone as quickly as possible in order to maximise the pressure difference across the primary turbine and to enable the rear slip stream zone to be quickly replenished with air, and thereby be more effective in reducing rear drag forces hopefully with as little expenditure of energy to detract from the benefits gained. In the latter respect, the suction ducting arrangements should add little to the overall energy requirements needed to propel the vehicle forward, and therefore the extra power these may give does not have to be paid for in terms of additional energy consumption.

This aspect, in relation to the partial vacuum beneath the car, is dealt with more fully in Section 5.6.

The Radial Flow turbine at the secondary stage, as used in Design 2, may not be the best type to use, since a retardation force against its rotation could be built up in the inter-turbine zone as the depletion of air between the turbine increases. It may be that this effect would not be offset by the benefits gained.

Thus, Design 1 is suggested as an alternative which uses Axial Flow air extraction units at the secondary stage. Again two units are used side by side in order to facilitate uniform extraction of air across the full width of the air tunnel. With this type of design, because of the near vertical pitch of the impeller blades, there would be virtually no retardation force build up resulting from the lowering of pressure in the inter-turbine region, discussed later in Section 5.2.3.

Therefore, providing these units employed very friction free ball-bearing housings for their central shafts they would consume very little energy in displacing air. Any that was used up should be far outweighed by the benefits gained in the energy conversion efficiency of the primary turbines and by the energy savings due to the reduction in rear drag forces.

Thus, theoretically one could have these secondary units rotating very fast in relation to the amount of air entering the system, such that the inter-turbine zone was taken down to a very low pressure indeed, with enormous advantages being gained in terms of air velocity and energy conversion across the primary turbine. This aspect is discussed further in the section following headed Secondary Turbine.

The remainder of this section deals in a more general manner with possible turbine impeller designs, as related to turbine arrangements.

Inevitably, many of the points already dealt with are further discussed

120

5.2.2 Primary turbine

There is, in fact a very wide choice for the possible design of the primary turbine and, as already indicated, these fall into two main categories.

(i) Radial Turbine designs placed horizontally in the path of the air stream, as has been used in Design 3;

(ii) Axial Flow designs placed vertically in the air stream, with the whole of it exposed to the full blast of the air stream, as used in Designs 1 and 2.

Within each of these two main categories there are a host of possible different designs and arrangements for the actual impellers of the turbines.

Axial Flow turbines

Examples of possible Axial Flow designs are as follows:

1) A windmill type of design.

As already mentioned this is the type possibly thought to be the best for this application under consideration, and aero blades are suggested, similar in design to an aircraft propeller.

It is thought that this design would be the most efficient in extracting the kinetic energy of motion of the air stream, since it's specially designed profile would take advantage of extra force benefits that could be gained from lift and torque components of teh air stream energy.

2) A ship's propeller type of design, with blade pitch optimised.

3) Air extraction fan type of design, again with blade pitch optimised for this particular application.

4) Aero jet engine type of turbine design.

This is by no means a comprehensive list of all the possibilities, especially when one considers some of the more futuristic car designs.

However, until the idea has gained acceptance and been proven under practical testing, I feel that the aforementioned suggestions are as far as one should go at this stage—although one is always open to further ideas as with the whole of this concept.

Radial flow designs for the primary turbine

These also lend themselves to taking advantage of induced lift forces through special wing profile designs for the impellers, and also for other design features aimed at acquiring more energy.

Considering the primary turbine of Design 4, in which a fairly straightforward wing design has been used for the impellers:

Firstly, to assist in the application of lift forces, I have placed small fixed vanes across the air stream just prior to the turbine entry, in order to more sensitively direct the air flow and to give controlled optimum angle of attack as the wing impeller rotates upwards through the air stream.

Considering the various stages as one of the impellers goes through one revolution of the turbine:

Stage 1—Figure 18

At point 1 one would try to create a lift force on the upper surface of the 'wing' due to lowering of local pressure caused by an increase in air stream velocity over the upper surface of the 'wing'.

In addition, this increase in the air stream velocity would impinge upon the next impeller at point 3, further adding to the impact force at that point.

Also, an increase in pressure would be starting to occur under the wing at point 2, assisting in the lift forces.

Stage 2—Figure 19

At this stage, one would try to again achieve increased air velocity over the 'wing' upper surface, giving some extra lift at point 4, but then the boundary layer would break away fairly rapidly giving a drag effect behind the 'wing' at point 1, which should act as a pulling force on the back of the 'wing'. The increase in the air velocity will again add to the dynamic pressure acting upon the next 'wing' at point 2.

Meanwhile at point 3 the main force is occurring which is being added to a little by the effect of the wing streamlining, as indicated.

Stage 3—Figure 20

Here the full impact of the air stream would be being felt on the front of the 'wing' at point 1. Meanwhile at point 2 would be a low pressure zone acting as a force pulling the 'wing' around in a downward direction at the rear. This force could be appreciably added to by the effect of a secondary turbine with a greater air displacement capacity than the primary turbine.

This would give an important aid to rotation.

Stage 4—Figure 21

In zone (a) there would be a comparatively low pressure which would enable a lower resistance to motion through this upward region, causing less drain on the angular momentum that the turbine acquires.

At point (b) I have included a small upturn air director, as indicated, which should have the effect of concentrating and accelerating over the last few inches before impact at point (c). On impact, a fast accelerating air stream would impart more energy than would an air stream at say a steady state velocity.

Therefore, the incorporation of such finer points in the design could make a substantial improvement in the energy conversion efficiency of the system.

A further design feature that may prove to be beneficial with this turbine would be to off-set the impellers so as to create a central void zone. In this way a high pressure vortex could build up, acting as a store of residual angular momentum energy which would help to maintain the rotation momentum. As shown on Figure 22. This illustrates the build up of a high pressure central vortex, A, spinning in the direction of the turbine, adding extra power behind the rotation.

This idea could possibly be combined with the incorporation of rear underside flaps on the wing impellers, as shown on Figure 23.

Such rear flaps can give improvements in the lift force exerted on the upper surface, as much as 100% increase in the power of the force. I have also illustrated fixed slats at the front which could also give a vast improvement in the lift force by sensitive manipulation of the air stream at the front of the wing impeller.

However, slats are normally a composite feature of the wing, and it may be that these impellers would benefit by having slats as a feature of the wing impellers themselves.

However, even in this case, one would still have to have the fixed slats in the air stream just prior to its entering the turbine, in order to give the optimum angle of attack between air flow and wing impeller.

The angular positioning of these slats will change, as illustrated, in order to facilitate constancy in the optimum angle of attack as the impeller rotates upwards.

One would probably try to create these extra lift effects up to about half way through the air stream height, then one would leave it to the natural action of the air stream impinging into the wing impeller, when the main force would be the frontal impact anyway.

An entirely different impeller design could be as shown on Figure 24.

The principal features of this design are:

a) a higher impact surface area on each of the impellers.

b) the build up of a high pressure vortex in the central region which could retain far more angular momentum energy than the previous designs.

Or a similar design to the above, but with four impellers, as shown on Figure 25. With these types of designs one could also probably create some lift forces on the upper surfaces of the impellers, as with the wing type designs.

Selecting the best primary turbine for this application would ultimately have to be determined under practical testing.

The next section deals more fully with the types and function of the secondary turbine, and again both cylindrical and circular designs are discussed.

2.3 Secondary turbines

Ideally, when the air stream collides with the impellers of the primary turbine it will pass on all of its energy of motion and come to rest. Work would then be required to remove that air from the system.

This work could be carried out in several ways:

(i) By the rotating impellers pushing the air away—this would extract back some of the energy given to the impellers;

(ii) By the follow-up air stream—this would reduce the energy content of the air stream that could be passed on to the impellers.

(iii) By the suctional drawing power of the underside partial vacuum and the rear drag forces. This would be the principal function of these forces, and it would be hoped that they would make a very substantial contribution in this manner. As will be discussed later the creation and existence of the partial vacuum does not require the consumption of any energy and thus it provides this suctional force without energy having to be given away. The rear drag forces are present anyway, and, therefore applying them in this manner is a way of obtaining something back from them.

(iv) The fourth way of removing the air is by means of the secondary turbine, and it is hoped that this turbine would operate in conjunction with the suctional force to remove the air as follows:

As previously discussed, it is intended to arrange, through interconnecting ducting etc. for the secondary turbine to run faster than the primary turbine and therefore have a higher air

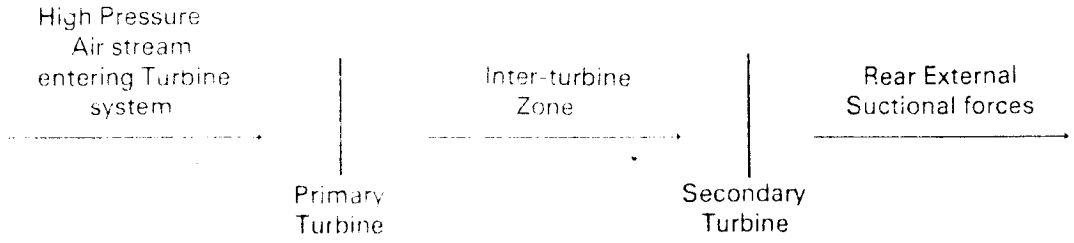
displacement capacity. This action would deplete the air in the region between the two turbines and create a drawing force on the primary turbine. In addition to this drawing effect, the pressure difference across the primary turbine will be increased and therefore incoming air will flow through the turbine at a faster rate. As indicated previously, it is hoped that this interaction between the two turbines will build up a self-sustaining action, with the primary turbine first causing the secondary turbine to rotate, then the secondary turbine increasing the flow of air.

Thus, this will increase primary turbine rotational energy, which will then increase secondary turbine rotation, and so on, until a higher power level is reached within the turbine rotational energy. In other words, by this interaction it is hoped that the induced air stream velocity entering the primary turbine will not be retarded back to a lower equilibrium velocity by the generator EMF, etc., as much as it would without the assistance of this action.

Therefore, more kinetic energy will be contained within the air stream and available for conversion into turbine rotational energy—keeping in mind that kinetic energy is proportional to the square of the velocity.

This equilibrium velocity state has been discussed previously in Section 5.1.2 under 'Frontal Design'. In order to obtain the maximum effect from the interaction between the two turbines, their relative speeds would have to be optimised.

Considering the following schematic representation of the system.



The interaction between the two turbines and the rear drag forces in displacing the air through the system could be in two principal ways, both dependent upon the speed/air displacement capacity of the secondary turbine:

(1) The pressure in the inter-zone could be at a level slightly higher than the external drag pressure, and under these conditions, this drag pressure would help to draw air from the secondary turbine, thus lowering the level of energy expenditure needed to displace the air by the turbine.

(2) Alternatively, and very probably better, one could arrange for the air displacement capacity of the secondary turbine to be higher than the volume of air entering the system, and in this way maximise the pressure difference across the primary turbine, and thereby maximise the amount of energy that could be extracted from the system. Under these conditions, the pressure in the inter-zone would probably be lower than the external drag pressure, and therefore additional work may have to be expended by the secondary turbine in pushing the air to the rear, rather than having it drawn out, as in the above case. However, on balance, the nett gains in the overall energy production could be appreciably better in this latter case.

Also, under the latter conditions, the displaced air would probably be more effective in saving the energy than would normally have to be expended in overcoming rear drag forces on the car body, this being another very important principle in the whole process.

Radial flow designs for the secondary turbine

As previously mentioned, a possible further function of the secondary turbine, particularly in arrangements which use radial flow designs, would be to capture any energy contained in the air stream which escaped at the primary turbine stage.

Thus, on the one hand, only minimal contact is desirable from the point of view of not having to give back any energy to the air, but on the other hand, one would wish a reasonable degree of contact in order to capture any of the energy remaining in the air stream after the primary turbine. However, as has been discussed previously, this would only occur with air from the fast moving periphery of the primary turbine, escaping at this point, but then impacting into the secondary turbine in its slowest moving region, towards its centre.

Therefore, with all of the aforementioned factors in mind, the positioning and design as illustrated on Figure 26 is suggested as a possible starting point for Design 3.

Figure 26

A — Primary Turbine Position.

B — Secondary Turbine Design and Position

Notes:

1. It is unlikely that a negative drag force would be exerted at 1, because of the abundance of air being issued forth from the turbine.

However, if so, conditions could be so controlled in order to minimise it to a negligible

2 Duct connected to the partial vacuum beneath the car to further extend the downward pulling force on the Primary impellers at 2.

Peripheral energy is more likely to escape from a Radial Flow turbine in comparison to an Axial Flow type. However, by using a design similar to that illustrated, it should be possible to pick up this energy at the secondary stage, and in this way for it to make a contribution to the overall rotational energy content of the turbine system.

Axial Flow secondary turbines

Of the possible Axial Flow designs for the secondary turbine, there is really only one which would be entirely suitable for this application, and, as already indicated, this would be a design along the lines of an air extraction fan. The action of this design is to slice off a thin section of air with each revolution and displace it on the other side of the extraction unit. Thus, only a very small work vector would have to be done against any horizontal suctional pulling forces, and also the drag forces would largely draw the air from the unit rather than the extraction unit having to do work to push the air through and outwards.

Finally, having discussed the dual turbine system in some detail, it may well be that under trials a single primary turbine would prove to be perfectly satisfactory, particularly in designs where one is applying all the additional suctional arrangements acting on the turbine exit. At this stage it really is a question of considering all the possible ideas and selecting from them a starting point for practical trials. I personally feel that a dual system would be very worthwhile testing from the point of view of better efficiency being obtained by:

1) maintaining air stream velocity closer to maximum theoretical velocity;
2) creating a higher pressure difference directly across the primary turbine;
3) more effective in reducing rear drag forces acting upon the car body.

5.3 Further discussion on the partial vacuum beneath the car

Discussed in relation to Design 3.

Figure 27 gives an illustration of a car of Design 3 type, travelling forward through an Air Passage at say 50 mph, and this is discussed below:

It is hoped to achieve a fairly high level of partial vacuum beneath the car, by means of the frontal section streamlining the air way, in order for this suction to then be applied to the turbine exists and in this way make a substantial contribution to the overall efficiency of the system. The principal way in which it would achieve this is by assisting towards maintaining the accelerated air stream velocity as it enters into the primary turbine system through its action of sucking the air through the system.

Thus, a higher level of kinetic energy of motion would be retained within the air stream, and hence a higher level of energy available for conversion into electrical energy.

The partial vacuum should be created without consuming any energy, which could result in a reduction in its nett contribution. Above the frontal section (in region 1 on the diagram) the air is being streamlined away very smoothly and rapidly. This fact acceleration over the surface will cause a low pressure on the upper surface which will partially overcome any resistance created to forward motion.

A projection of this type would normally create high drag forces at its rear. However, because in this case an abundance of air is issuing out at the rear, the drag forces behind the frontal section will not be felt as drag forces on the car as a whole, and therefore they will not increase the car's resistance to forward motion. It will simply be a suction force contained within the boundaries of the travelling car, totally separated, as far as the rear is concerned, from the rear external atmosphere, where the creation of the external drag forces acting upon the car takes place.

Another aspect of the partial vacuum is that it will be very beneficial in overcoming upper surface lift forces created by the high level of streamlining, since it will exert a strong downward vertical pull on the underside of the car.

Such a downward force will not add to the car's resistance to forward motion. In this respect the partial vacuum should in fact be beneficial, since the frictional drag forces on the underside of the car, between car body-air-ground, could be lowered, and also possibly the tyre to air frictional forces could be less.

A further benefit is that the additional air that is displaced at the front joints forces with that streaming towards the turbines, and this will combine to give a higher available energy content in the air stream.

Therefore all the benefits in energy efficiency, gained by application of the partial vacuum at the exit to the turbine system should be acquired without any energy expenditure to detract from the overall benefits gained.

5.4 Generator—some related design considerations

The rotational energy acquired by the turbine system has to overcome the electro-motive forces set up within the generator as the power input is increased. The efficiency at which transference of power can be improved by optimising between the two variables, speed of generator rotation and size of

generator, in order to determine the set of conditions which give a peak energy production for a given strength of power source.

One could carry out this optimisation at the speed the car is normally driven at, say a cruising speed of 50 mph.

However, at lower speeds the power source will be less and the generator may not be performing at its peak efficiency for the lower power source. The speed of generator rotation, as pre-determined by the gearing ratio between turbine and generator set for a car speed of 50 mph, could be lower at the lower car speed than was required to give maximum generator performance for the power source.

Therefore some form of variable gearing system between turbine and generator would probably be beneficial in order to facilitate higher speed ratios at lower car speeds, i.e. at a lower power source.

Adjusting this gearing ratio would be another useful function for an on-board computer.

The computer could be pre-programmed with the optimum gearing ratios over a wide range of car speeds and activate appropriate adjustments in response to the car speed being fed into the computer on the input side.

As far as the size of the generator is concerned, there may be a case for having the power transmitted to two or three small generators instead of one larger one. This is deiscussed further in Section 6.1 (b), in relation to Design 5 in which two separate air streams are used.

5.5 Battery system—some design considerations

The batteries are present in order to perform two main functions:

(a) to provide a store for over-produced electrical energy for use when the generator is under-producing with high power required by the car, say when accelerating;

(b) to provide a constancy in the rate of supply of electricity being transmitted to the electrical propulsion system.

These functions can be carried out simultaneously within the same battery bank. However, if the car undergoes a journey in which the overall energy usage is higher than the energy produced in that journey, for instance because of a very heavy load in unfavourable terrain, then there may be advantage gained by having an auxiliary spare battery bank, to be brought into use when the charge in the main battery store becomes low.

There is a gradual reduction in the efficiency of a battery as its charge gets lower, and by bringing in a fully charged battery into use at some stage during the journey, one would maintain a higher efficiency for a longer period in the journey.

This is illustrated on Figure 28, which shows a graph of Battery Efficiency against Battery Charge Reduction during the course of a journey.

The dotted line indicates the fall in efficiency that would have taken place had an auxiliary battery not taken over.

Point A is the point at which a change over to an auxiliary battery takes place.

As can be seen from these two curves, battery efficiency is maintained at a higher level for a longer period over the journey. This would mean that speed and power levels could be maintained for much longer during the journey with respect to the electrical propulsion system. However, at the end of the journey both systems would probably have to be topped up by similar amounts of charge from an external source in preparation for the next journey. Therefore, probably no gain in this respect, but the extension of higher efficiency levels, would be very beneficial during the journey, making the driving easier and giving the car greater compatibility with other road users. Here in lies one of the great advantages of the car being proposed, over current electrically propelled vehicles, in that the power being produced on the spot would normally always ensure the maintenance of speed and power levels, no matter how long the journey. Apart from the economic considerations.

As the calculations indicate in Section 6, is is believed that over the full length of most journeys sufficient energy would be produced to fully satisfy the power requirements of the car during the journey. However, there would obviously be exceptions to this equalising situation which would justify the incorporation of the auxiliary back-up battery.

Accommodation of the batteries within the car should be no problem these days, with recent advances being made in weight reduction, size compacting, and meeting the requirements of unusually shaped space facilities.

Monitoring of battery efficiency in relation to charge depletion could be another function of an on-board computer.

A further addition to the electrical system could be as follows:

During periods when the generator(s) was producing more electricity than was required by the electric motors for propulsion, for instance during a cruising period, one could supply the electric motors directly with the electricity being produced by the generator and feed any surplus electricity into the batteries for storage using an appropriate electrical arrangement. In this way one may be able to significantly reduce energy losses through the battery system.

5.6 Materials

The weight of a vehicle is a very important factor in the overall power requirements of the vehicle. The car that I am proposing has an advantage over conventional petrol engine cars in this respect.

since most of the component parts of the system can be manufactured from fairly light-weight materials. This is because they do not have to withstand the very high heat and pressures of an internal combustion engine. Thus, extensive use could be made of light-weight plastics for such components as the turbine impellers, and casings of batteries, generators and electric motors, etc.

Aluminium could also be used quite extensively, combining impact resistance with light-weight. Fibre glass would also be a good material, possibly for use for the main shell of the car.

All the above materials are in common use for similar applications, and therefore it should be a fairly straight-forward matter to produce a first model, using an appropriate combination of the above materials.

As already indicated, Design 1 is being suggested as a possible design for a first prototype.

At this stage, a possible approach would be to acquire an appropriate conventional chassis, together with its steering system, and simply replace the drive system with a suitable electric motor installation, then build the superstructure to fit the chassis in accordance with Design 1, 2 or 3.

Fibre glass would be used for the main shell of the car, with possibly aluminium being used for the upper unit and for the turbine housings and ducts. Hopefully the turbine units and extraction fans could be obtained off the shelf for this first prototype.

Possibly a material and component cost for this first prototype would be somewhat in the region of £10,000.

For a material in the longer term I am of the opinion that the latest advances in the newly emerging range of very high impact resistant glass would be ideal for this application, not only for the car body, but also for many of the component parts, such as the turbine impellers.

In order to ensure good streamlining and for minimising friction drag, it is very important to have a very smooth body surface finish, and glass would possibly be the best material in this respect.

The high impact nature of the new glass materials now brings glass within the realm of car body application, and in the particular application being considered this property would also greatly overcome the problem of streamlined surfaces becoming impaired through surface blemishes.

Such a car body would also withstand everyday bumps and knocks far better than would current materials, either steel or ABS plastic.

A further advantage would be that the windscreen and other windows would automatically be made of this high impact glass, and therefore safety would be improved.

At the moment this type of glass is not being used extensively for windscreens on cost grounds. However, were this glass to be used in large quantities for the mass production of entire car bodies, then its cost would obviously be reduced substantially, and even at this time it would probably be comparable in price with a steel body.

Another consideration is that the substances from which this type of glass is made are present on Earth in some abundance, in contrast to metals and oil related plastics which are over-used resources of the Earth.

This glass might also facilitate better colouring methods, with internal pigmentation rather than an external paint finish. However, a paint finish would be perfectly satisfactory, without impairing the quality of surface finish, if internal pigmentation proved impracticable, say possibly due to lack of sufficient heat stability.

Obviously, if the latter method was possible, then there would be the advantages gained in diminishing the effect of scratches from the point of view of appearance.

In addition to all of the above benefits, it is a comparatively light-weight material with high structural strength, having a density approximately one third that of steel.

Thus, all of these factors, in my view, add up to this material being a very serious consideration for use, not only in the particular application under consideration here, but also for car bodies in general, and possibly even applications such as coaches and trains.

The following news report gives some support to may views concerning this type of glass:

Newspaper article

Quote: 'Now, Car Engines of Glass'. Glass car engines giving 100 miles to the gallon are being developed in Japan. The NGK Company, who make sparking plugs, have already produced a 50 c.c. motor-cycle engine in silicon nitride—basically glass. It is running now. The next step is a car-size glass engine with cylinders, head, crankcase, crankshaft and pistons, all made up of ceramics, a substance similar to the glazing on bathroom tiles and kitchen sinks. The weight is cut by half compared with a conventional metal car or motor-cycle engine—and this means extra fuel economy. But there is another plus: a glass-ceramic engine need never wear out.

Another Company, Kurasaki Refractories, has developed a new silicon-glass-material said to withstand sudden temperature changes better than steel. Yet with a third of the density of steel it is lighter in weight and cheaper to produce—and it could be longer lasting.

At Isuzu—who are linked with General Motors, parent company of Vauxhall and Opel—engineers working with Kyocera Ceramics are developing an all ceramic-glass two-litre diesel engine. End Quote.

A further advantage of these materials would probably be in the ease and cost of recycling car

bodies for further use, and a main advantage would, of course, be the inherent long life of cars made from such materials.

6 Verification of the feasibility of the idea by calculation

6.1 Calculation to determine the amount of energy produced by the turbine system

(a) For the purposes of this first calculation, I have considered the conditions of a vehicle, as given in Design Three.

As discussed in Section 4, when describing the Venturi effect, no significant air compression takes place on streamlining air and causing it to pass through from a broad section into a narrower section. Instead, the velocity of the air increases to compensate for the reduction in space, in accordance with Bernoulli's Law.

Theoretically, therefore, this increase in velocity should be inversely proportional to the cross-sectional areas of the sections through which the air is flowing.

For the purposes of this calculation, I will use a vehicle speed of 50 mph, this being a normal cruising speed for road transport. This is approximately equal to 75 fps (feet/sec). Therefore, if one assumes that the car is travelling through a fairly still atmosphere, then there will be a relative air wind speed at the front of the car of 75 fps (i.e. equal to the speed of the vehicle) confronting the forward moving vehicle.

The cross-sectional area at the front of the car, i.e. the start of the air stream tunnel is approximately equal to $32\frac{1}{2}$ square feet ($6\frac{1}{2}$ ft × 5 ft). —Figure 29.

This cross-sectional area gradually decreases as the air streams through towards the rear of the car until at the point of entry to the Primary Turbine the cross-sectional area is equal to:

$$1\tfrac{1}{2}\text{ ft} \times 3\text{ ft} = 4\tfrac{1}{2}\text{ square feet}$$

Therefore the theoretical speech of the air as it enters the turbine system is equal to:

$$75\text{ fps} \times \frac{32\frac{1}{2}}{4\frac{1}{2}} = 540\text{ fps}$$

However, there are a number of reasons why the air stream velocity will probably not reach the full theoretical speed:

(1) In reality, there will probably be a Maxwell-Boltzmann type of velocity distribution of the air molecules over the cross-section of the air stream, both in the vertical and horizontal directions, due to frictional surface drag. Hopefully, however, the boundary layers on all of the surfaces which make up the air stream tunnel will remain relatively intact, given a suitable surface finish. This being the case, then the air streams will reach maximum velocity (for a given cross-section) fairly close to the surfaces of the tunnel.

However, to make allowance for this effect, I will reduce theoretical air speed by 5%.

(2) On impact of the air stream with the impellers of the turbine, air molecules will pass on their acquired kinetic energy of the motion to the impellers, causing them to rotate about the axis of the turbine.

Once this rotation has been set in motion, then the turbine will contain a certain amount of momentum energy which will contribute towards sustaining the rotation of the turbine.

Therefore, the total amount of energy now present in the system will be that due to the kinetic energy of motion of the air stream plus the acquired momentum energy of the turbine.

Unfortunately, we are not dealing here with a totally elastic collision because of the back EMF of the generator and the mechanical frictional forces.

This means that the rotation of the turbine will be under a restraint and will not be able to give a free response to the impact of the collision. This will have a slowing down effect on the speed of rotation, compared with theoretical speed, which in turn will have some slowing down effect on the velocity of the air stream.

However, the accumulative effect of the design feature, mentioned in Section 5, should help significantly to overcome retardation effects.

A summary of these design features are given below.

They are taken from all the car designs suggested and do not all apply to any one single car design although Designs 1, 2 and 3 contain most of the more important ones.

1 The suctional power acting upon the exits to the turbines by:
- a the partial vacuum beneath the car;
- b the rear slip stream forces;
- c the secondary turbine assisting in the application of the above;
- d the upper surface Venturi suction force.

Probably the overall accumulative effect of all of these suction forces would be equal to that which would be obtained from the volume of the displaced air at a pressure, P, the low local pressure in the other half of the Bernoulli's equation, i.e.

$$P \text{ in } P+\tfrac{1}{2}\rho V^2=C$$

($\frac{1}{2}\rho V^2$ being the increased dynamic pressure of the air stream entering the turbine system) Although the point must be made that they are not, in fact, two halves of the same equation, they nonetheless should approach similar orders as though they were.

2 The special design features in the air stream tunnel, i.e
   a Venturi shaped entry, causing rapid air acceleration on entry into the final approach;
   b the tear drop profiles in the air tunnel to sustain this air acceleration and act as one way valve systems;
   c the design features causing air acceleration right at the point of entry into the primary tunnel.

3 The special impeller design features, e.g.
   a creation of lift forces;
   b creation of residual rotational energy is the central region.

4 Car body surface finish, this being very streamlined and smooth in order to maintain the boundary layer as much as possible.

5 Optimisation of the generator speed, in relation to the strength of the variable power source, by means of interconnecting variable gearing.

6 The minimising of all the rotational mechanical frictional forces connected with the energy production process by using ball bearing shaft housings and light oil drip feeds.

However, in spite of these design features, there will be some retardation of the air stream velocity and therefore I will make a very generous allowance of a further 25% reduction in the theoretical air stream velocity as it enters the turbines.

In addition to this, I will not include the acquired momentum energy of the turbine in the calculations.

Therefore, for the purposes of this calculation, I propose to use an air stream velocity of 385 fps this being 155 fps less than the theoretical of 540 fps.

Just to reiterate, this represents the velocity of the air stream at the point it impacts into the impellers of the turbine, after reaching a steady state equilibrium flow rate, at a car cruising speed of 50 mph, having made full allowances for retardation factors.

The velocity of the air stream is govenered by the Bernoulli's Law, i.e.

$$P+\tfrac{1}{2}\rho V^2=\text{Constant}$$

(where P is the local low pressure created by the air stream on the body surfaces
ρ is the density of air,
V is the velocity of the air stream).

The expression '$\frac{1}{2}\rho V^2$' represents the increased dynamic pressure of the air stream due to its increased velocity, and quantifies the kinetic energy, E, of the air stream.

Thus $E=\frac{1}{2}\rho V^2$.

This is the same as the expression '$E=\frac{1}{2}mv^2$', which quantifies the kinetic energy of any moving body, but in the case here, related to air. With mass, m, being replaced with the density of air ρ.

For the purposes of this calculation, I will use an air density of 0.08 lbs per cubic feet.

Thus, the kinetic energy of motion of the air stream will be as follows:

$$E=\tfrac{1}{2}\times 0.08\times 385\times 385$$
$$=5929 \text{ Ft lbs/square Ft/sec}$$

Therefore, the total force acting upon the impellers at the point of impact will be the above kinetic energy x the cross-sectional area of the air stream tunnel at the point of entry into the turbine, i.e.

$$E \text{ total}=5929\times 4\tfrac{1}{2}$$
$$=26680 \text{ Ft lbs/sec}$$

Since it is more familiar to express energy in terms of Horse Power when referring to a car, I will convert as follows:

$$E \text{ HP}=\frac{26680}{540}=50 \text{ HP}$$

If we assume that the turbine system has an energy conversion efficiency of 66%, then the amount of energy being transferred to the battery storage system will be equivalent to—

33 Horse Power

(b) Two turbine system—as in Design Five

Briefly, the calculation for the two turbine design, as illustrated in Design Five, is as follows.

In this case, the entries to the turbine systems both have a cross-sectional area of 3 feet×0.75 feet=2.25 square feet

(1) Upper unit

Theoretical air stream velocity $= \frac{17.5}{2.25} \times 75$ fps

$= 583$ fps

Velocity after a 5% and a 25% reduction correction $= 415$ fps

$$\text{Therefore, } {}^{E}HP = \frac{\frac{1}{2} \times 0.08 \times 415 \times 415 \times 2.25}{540}$$

$= 29$ HP

—assuming a 66% energy conversion, the turbine produces

19 HP

(2) Lower unit

Theoretical air stream velocity $= \frac{15}{2.25} \times 75$ fps

$= 500$ fps

Velocity after a 5% and a 25% reduction correction $= 356$ fps

$$\text{Therefore } {}^{E}HP = \frac{\frac{1}{2} \times 0.08 \times 356 \times 356 \times 225}{540}$$

$= 21$ HP

—assuming a 66% energy conversion, this turbine produces

14 HP

Therefore, the combined energy production of the two turbines is equivalent to

33 HP

This is the same as the single turbine system, but in practice it could possibly prove to be better since the smaller sized generators of the dual system will have a lower back EMF than the larger turbine and therefore they may not slow down the velocity of the two air streams as much. This being the case, then higher impingement velocities could probably have been used in the calculations, with perhaps a 20% reduction instead of the 25% allowance.

With this correction, the energy produced is as follows:

Upper unit	22 HP
Lower unit	16 HP
Combined Energy	38 HP

(3) Axial Flow turbine systems

In carrying out these calculations it has appeared that an impact surface area of about 4.5 square feet is about the optimum area

This would apply equally to Axial Flow turbine impellers as well as to the horizontal impellers of a Radial Flow turbine.

Thus, in a case where two Axial Flow turbines are standing side by side in the air stream, the optimum diameter of the turbines would be 1.7 feet.

In the case where one turbine might be used, then its diameter would be about 2.4 feet.

In both of the above cases, with the same 4.5 square footage of impact surface area, then the energy in the air stream at the point of impact will be as previously calculated in the case of the drum shaped turbine, i.e.

50 HP

If these turbines have a 66% conversion efficiency, then the electrical energy produced would be 33 HP, as estimated for the Radial turbines. However, it is possible that these Axial turbines might give a higher energy conversion than 66%.

On the other hand, in order to acquire the maximum efficiency from the Axial turbines, the pitch angle of the turbine impellers may be such that they will lower the strength of the power source by knocking back the air stream velocity.

Therefore, one would have to optimise between this effect and the optimum angle for energy conversion, and it may be that the nett effect would be that Axial turbines were less effective than the drum shaped type for energy production.

6.2 Calculation to estimate drag forces acting upon the vehicle

The drag forces for this are a little difficult to estimate at this stage without the benefit of practical experience with this car. However, I will endeavour to make some estimates, as follows, bearing in mind that it is believed that this car would, in fact, have less air resistance to forward motion than a normal car for reasons that will be further discussed.

Drag forces are the restraints placed on a vehicle to its forward motion by the air passage. The resistance has two components: (1) form drag, which is dependent upon the ease with which a vehicle can displace air with its shape, and (2) friction drag, which is dependent upon the car body to air surface frictional forces. This is very sensitive to the smoothness of the surface finish of the car body.

The combined drag forces can be estimated using the following equation:

$$\text{Drag HP} = \frac{Cd \times A \times V^3}{146.600}$$

(where Cd=Drag co-efficient of the vehicle
A=Cross-section of the car body at the maximum point, in square feet
V=The speed of the vehicle in MPH)

At the extremes, the drag co-efficient of a vertical plate at right angles to direction of travel is equal to about 1.2, whereas for a perfectly streamlined 'tear-drop' shape the drag co-efficient can be as low as 0.03.

A normal saloon car has a drag coefficient of 0.5 and the latest streamlined models are approaching 0.35.

The way I propose to estimate the drag forces on the vehicle under consideration here, as shown by Design One, is to first calculate the drag forces on the very worst case of a moving body with the dimensions of this vehicle, and then apply a knowledgeable correction, having regard to the design features of the actual vehicle under consideration here.

Thus, the worst case would be to use a drag co-efficient that applied to a shear vertical surface at the front of the vehicle confronting the air passage, i.e. CD=1.2, with a surface area of 32.5 square feet in our case. This would represent a moving body with no streamlining features whatsoever to help in the displacement of air.

Thus,

$$\text{Total Drag HP} = \frac{1.2 \times 32.5 \times 50 \times 56}{146.600}$$

$$= 33 \text{ HP}$$

It is interesting to note that this figure is exactly equal to the amount of energy that was calculated to be produced by the turbine. One might expect this to be the case, hence giving support to the previous calculation, since in effect this air resistance value does represent some indication of the amount of available energy contained in the air bounded by the 32.5 square feet at the front of the vehicle, albeit reduced by a number of factors.

Thus, in this case, one would be producing sufficient energy to overcome the air resistance of the vehicle, but one would have to add additional energy to overcome mechanical and tyre frictional forces etc.

However, in the actual vehicle under consideration here we, of course, are not dealing with a solid vertical surface at right angles to forward motion. Rather we have a highly streamlined car body with the displaced air streamlining through the vehicle and being allowed to pass through and emerge out at the rear of the vehicle, hopefully with as little impedance to its overall flow rate as possible.

The turbine system will obviously cause some resistance to flow rate, and in the previous calculations I allowed for a 25% retardation of the overall air stream flow rate.

As soon as the turbine rotates at all, air passes through and out at the rear of the vehicle, and therefore the resistance to forward motion due to the air is beginning to decrease compared with the case where one has a solid vertical front which has to expend a lot of energy in pushing the air aside.

I estimate that the turbine should be rotating at about 50—80 revolutions/sec at the cruising speed of the car, i.e. 50 mph. This represents a high air displacement capacity, and therefore the overall air resistance to forward motion will be appreciably lower than would be the case with a solid front having no outlet through which the air passage can pass.

Therefore, probably a very fair estimate would be to make a 50% reduction in the air resistance of the air turbine car, compared with a car which has a solid vertical front.

However, in practice one might expect this turbine car to have a lower air resistance than is represented by the above value.

This is because the turbine car would also have very much lower drag forces acting upon its rear body, since the air is being displaced into the rear region which will have a very significant effect in reducing rear drag forces.

Therefore, not only would one expect to have improved frontal resistance to forward motion, but also for air resistance to be very much improved at the rear.

If all the principles being applied were to operate fully 100% effectively, then the only drag forces on the car would be those due to surface air friction which, because of the streamlined nature of the car and the very smooth surface finish, would be very low indeed compared with the drag co-efficients normally obtained with road vehicles —say around 0.5.

However, not withstanding the above comments, I will use a drag co-efficient for the turbine car of 0.6, this representing 50% of the value of a car which has a solid vertical front, having no streamlining features.

Therefore, using this value, the energy expenditure due to the air resistance of the turbine car would be equal to

16.5 HP

The following table summarises all of the results obtained and will assist for ease of reference in the further discussions that follow.

Summarisation of the results

Car design	*Relative air wind speed at the front of the vehicle effected by the speed of the vehicle*	*Theoretical air stream velocity at entry to turbine due to air streamlining*	*Actual air stream velocity used after correction for retardation factors*	*Kinetic energy of motion of the air stream on entering the turbine system*	*Energy conversion to electrical power assuming 66% efficiency*	*Estimated air reistance to forward motion of the car*	*Energy remaining to overcome forces other than air resistance*	*Energy remaining as a % age of total electrical energy produced*
Single air stream system e.g. as one design	75 fps	540 fps	with correction of 5%+25% 385 fps	50 HP	33 HP	16.5 HP	16.5 HP	50%
Two turbine system i.e design five	Upper unit		with corrections of 5%+25%					
	75 fps	583 fps	415 fps	29 HP	19 HP	Although not estimated for this design the values should be about as above, i.e.		
	Lower unit 75 fps	500 fps	356 fps	21 HP	14 HP			
	Combined results:—			50 HP	33 HP	16.5 HP	16.5 HP	50%
			with corrections of 5%+20%			As above		
	Upper unit	583 fps	442 fps	33 HP	22 HP			
	Lower unit	500 fps	380 fps	24 HP	16 HP			
	Combined			57 HP	38 HP	16.5 HP	21.5 HP	56.6%

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6.4 Further discussion of results

For a conventional car, over the full length of a journey, about half of the energy is consumed in overcoming air resistance and half for other power requirements of the car, i.e. mechanical friction forces, tyre to road friction, acceleration and maintaining speed.

One would expect the turbine car to use up energy for the latter functions at about the same rate as a conventional car.

Modern saloon cars are given the familiar Horse Power rating, and for most cars this is about 50 HP.

This rating gives an indication of the maximum power achievable by the car during say a fast acceleration move, or for steep gradient work, or with a very heavy load on board.

At a normal cruising speed in relatively flat terrain, the power being expended by the car is substantially less than the above rating, possibly in the region of 20 Horse Power.

In fact, it is worth commenting here that one of the latest innovations on the new breed of aerodynamic shaped cars is to incorporate a device which disconnects the engine intermittently, relying solely on the acquired momentum energy of the vehicle for forward propulsion, resulting in a very substantial saving in power requirements.

This, therefore, demonstrates the very low rate of power input that is sometimes required by a car during its journey. It is the same effect as one experiences on a child's scooter when, after having built up the speed with high energy input, then it only requires an intermittent input of a relatively small amount of power in order to maintain the speed. In this particular example the person on the scooter represents a large proportion of the mass involved with the acquired momentum energy of the scooter.

Similarly, this would be the same in the case of a car, but not to the same extend.

The turbine car that is being proposed would produce energy at the rate of 33 HP/sec at a cruishing speed of 50 mph, in accordance with the calculations.

Assuming we can compare with a normal car, then this level of energy produciton would be about 10—15 HP more than the car was consuming at the cruising speed of 50 mph.

Thus, during cruising 10—15 HP would be being supplied to the batteries purely for storage, for use when the power requirements of the car was in excess of that being produced by the turbine.

One would hope that over the full length of a journey the total power produced en route would totally satisfy the demands of the overall power requirement of the car during the journey.

If this proved to be the case, as seems likely, then this in my opinion would represent an exceptionally important innovation, particularly at this time when oil is running out; petrol and energy costs are soaring; and pollution is becoming intolerable to society.

Hence, the length of my report in order to try to establish the concept.

7. G A Drawing notes

Some additional extracted general notes on the following G.A. Diagrams Section, related to Design One:—

A—In this region the airstream is split, streamlined and channelled into two separate streams in the final approach to the Axial Turbines.

B—Two Axial, windmill type, Turbines standing side by side facing the two halves of the split air stream.

C —Two air extraction fans standing side by side, which, through the inter connecting gearing, are arranged to assist removal of the air at an optimised rate.

D— Air Suctional Ducting arrangements.

E—Partial Vacuum beneath the car created by the frontal scoop.

(See relevant text for fuller explanations of the systems).

Claims (Filed on 19th Jan 83)

1. The invention is a method producing electrical power in situ for use in the propelling of a moving vehicle through an air passage.

The electrical power is produced by first capturing as much as possible of the air in the moving vehicle's air passage at the front of the vehicle, then streamlining and channelling the air towards the rear of the vehicle, and into a relatively small cross-sectional area, achieved by appropriate design of the vehicle body. In this way the whole of the air in the moving vehicle's air passage is collected, streamlined and accelerated to a relatively high velocity compared with that of the moving vehicle.

The accelerated air will then contain an increased level of energy, sufficient to provide all the power, or most of the power, for all the drains on the vehicle's power consumption.

The energy of the accelerated air stream is harnessed by means of placing an air turbine system appropriately positioned in the path of the streamlined air, towards the rear of the vehicle. A generator is connected to the air turbine effecting conversion of the mechanical turbine rotational energy into electrical power. The electrical power so produced is fed to an electric motor system which propells the vehicle. The electricity can be fed to the electric motor either directly or, via a battery storage system, dependant upon the power output to power input ratio. (See the General Arrangement Diagrams for possible designs of a road vehicle). This general claim is concerned with the process of generating the

power, which can be applied to any moving vehicle travelling through air, rather than to the use of power so produced by the electric motor system.

The distinguishing features of the invention are as follows,—which will also serve to give a better understanding of the inventive concept:—

Unlike normal generation of electricity by wind power which requires a naturally produced flow of air from a natural high pressure to a low pressure region, this method of electrical power generation can take place when the vehicle is moving through air which would otherwise be still, containing no variations of pressure to produce a wind. The air turbine rotation being effected by the action of the accelerated streamlined air, induced by the forward motion of the specially designed vehicle.

The collecting of all the air in the vehicle air passage, then streamlining and channelling the air through into a smaller cross-sectional area, at entry to the air turbine system, is a necessary feature of the process and distinguishes this process from other possible inventions where a turbine or windmill device may be mounted on a vehicle for the purposes of producing some electrical power from any potential energy that may be harnessable simply due to the relative motion of the vehicle to the surrounding air. Such a device would not produce a nett gain in energy, with drag forces being created equal to whatever small fraction of electrical power may be created by this means. Therefore, such a process would obviously bear no comparison to the very much more complex process of accelerating a maximised quantity of air by special shaping of the vehicles body in order to first increase its energy content before harnessing the energy. In effect in this process the energy of the moving vehicle is first given to the surrounding air in the vehicle's air passage and this energy is then given back to the vehicle via the air turbine system, all taking place in situ whilst the vehicle is travelling forward.

This process of energy transference is apparent from a consideration of the Bernoulli's theorem, as applied to the streamlining of air by a moving body passing through an air passage.

This theorem states that

$$P + \tfrac{1}{2}\rho v^2 = \text{constant}$$

Where P is the static pressure of the air stream and $\frac{1}{2}\rho v^2$ is the air stream's dynamic pressure, or forward kinetic energy of motion. ρ is the density of air.

The higher the level of streamlining achieved, and the smaller the cross sectional area achievable at entry into the turbine system, the greater will be the acceleration of the streamlined air and the higher will be its velocity on entry into the air turbine system. Since the dynamic pressure is related to the square of the air velocity, rather than directly to the velocity, then a higher dynamic pressure can be obtained from a given volume of air in the air passage, the higher the velocity of accelerating air. The higher the dynamic air pressure that can be induced by streamlining and channelling the air, in the manner described, then the higher the level of forward kinetic energy of motion induced into a given volume of air and the more the turbine rotational energy that can be obtained from the given volume of air. Thus by collecting, streamlining and channelling as much air as possible from the air passage through which the vehicle is moving, and then by passing the streamlined air through an optimised minimum cross-sectional area at entry to the air turbine system, the quantity of air for providing energy will be maximised and the acceleration of the air will be maximised, and therefore, its relative forward kinetic energy content will be maximised and substantially increased. The accelerated air will then contain sufficient energy to not only provide power for the resistance to forward movement of the vehicle through its air passage due to form drag—this being the energy that one might expect to be obtained from some other process where no streamlining and channelling into a small cross sectional area took place,—but also sufficient energy to provide for all the other drains on power consumption such as frictional drag and mechanical friction etc.

Whilst in some other process form drag and frictional drag forces would probably negate the power produced, in this process a further distinctive feature is that the vehicle body design and shaping will be such that suctional forces due to form drag will be concentrated as much as possible on the exhaust side of the air turbine rather than being applied to the body of the moving vehicle. In this way, therefore, the drag forces will make a contribution to the power production, rather than add to the power requirements of the vehicle. See also additional claim 1A.

Another distinguishing feature of the process is the fact that, at times, the electricity being produced could possibly be fed directly to the electric motor system, by-passing the battery storage system, but with any excess energy being stored in batteries. This would be at times when the power requirements of the vehicle were less than the power being produced by the turbine generator system e.g. during cruising or travelling downhill. The stored excess energy during these times would then be available to draw on when the vehicle required more power than was being generated, e.g. going up hill.

Thus in this way one would save on energy losses that may occur in passing the electricity through a battery storage system.

Dual air turbine system

The process discussed in the general claim could probably function with a number of different air

turbine systems, as stated in the specification request, but a particular system which I wish to claim is as follows, (more fully described in the request specification).

This air turbine arrangement comprises a dual system of turbines in which a secondary turbine, also functioning as an air extractor fan, is placed after the primary turbine in the path of the streamlined air.

The two turbines would be connected by a suitable arrangement and gearing system. This gearing would be such that when the first primary turbine was caused to rotate by the impact of the air stream the second turbine/extraction fan would be caused to rotate somewhat faster and have a higher air displacement capacity than the air passing through the primary turbine.

The secondary turbine would have two functions (i) capturing any dynamic pressure remaining in the air stream after passage through the air turbine, and (ii) acting as an extraction fan to give rapid displacement of the air to the rear of the vehicle for the removal of drag forces that may otherwise be acting on the body of the moving vehicle.

Thus, the main inventive concept here being that the suctional drag forces, always associated with a moving vehicle, would by this means in effect all be transferred to the exhaust from the primary turbine, where they will enhance the power production, and away from acting on the body of the moving vehicle, when some would add to the power requirements of the vehicle.

For the secondary turbine to perform both these functions, design and relative speed of the turbines will be critical.

This dual arrangement of turbines would also contain inherently within the system a self sustaining action, once the rotational momentum energy of the turbines has been established, due to the slightly higher suctional action of the secondary turbine on the primary turbine.

New claims or amendments to claims filed on 24.11.83.
Superseded claims 1, 1A.

New or amended claims:—

1. An air and electrical power propulsion system, applicable to either a road or rail vehicle, in which the basis of the main system involved is: — (i) The inducement of a maximised quantity of forward kinetic energy into a maximised quantity of the air of the said vehicle's air passage using a said vehicle, which could be of a variety of shapes, such as to cause maximised air displacement and creating the said forward kinetic energy by means of a high degree of air streamlining, principally by the design shaping of the said vehicle. Then to convert the said kinetic energy so induced into electrical energy by means of an air turbine system with connected generator, suitably positioned in the said vehicle for use then in powering the said vehicle. The said air turbine system being generally positioned as far as practically possible to the rear of the said vehicle in order to facilitate for maximum streamlining effect, and said forward kinetic energy inducement into the air and the said generator being positioned and connected to the said air turbine system so as not to be in the pathway of the said air stream flow through the said vehicle. The electrical energy produced by the said air turbine and generator system in the main being fed to an on-board battery storage system, from where the electrical energy is supplied to the said electric motor system. On occasions though being fed directly to the said electric motor system. (ii) The application of the said moving vehicles associated rear drag forces onto the rear of the said air turbine system at a maximised level in order to then increase upon the potential for energy extraction from the said air stream flow, mainly by virtue of effecting an increase in the pressure drop across the appropriate stage of the said air turbine system. (iii) The minimisation of the said rear drag forces acting upon the rear body of the said vehicle by virtue of rapid replenishment of said vehicle's wake zone with the said air flow exiting from the said air turbine system. Thereby, increasing the nett energy balance of the said air and electrical propulsion system. The said electric motor aspect of the said propulsion system and it's connection to the wheels of the said vehicle, along with the steering, speed gearing, and other aspects such as lighting, probably being of hitherto known conventional design but not necessarily.

2. A vehicle in which the system of Claim 1 is achieved by means of first capturing then streamlining the whole of the air of the said vehicle's air passage over the upper surfaces of the main body of the said vehicle, in which the driver and passengers would be seated, from the front to the rear of the said vehicle to where the said air turbine system is positioned towards the rear. An upper overhead hollow and specially shaped canopy structure being used, generally extending the entire length of the said vehicle and being the full width of the said vehicle at the front, for the purposes of maximising the capturing of the air of the said vehicle's air passage and then to aid in it's streamlining and air velocity acceleration on flowing towards the rear of the said vehicle. The said upper unit in combination with side walls, in effect forming an air streamlining tunnel with the said upper surfaces of the said vehicle. The said air tunnel decreasing in dimensions from the full height of the said vehicle, and down to a lesser extent in the lateral plane, from the front of the said vehicle to the rear to optimum horizontal and lateral dimensions at entry to a corresponding optimised sized said air turbine system. The said air tunnel being the upper surfaces of the said main body of the said vehicle at the base of the

said air tunnel, the said main body being generally, although not necessarily, of a half teardrop shape in the length cross-section with the largest end at the front of the said vehicle, this being a shape to give maximum air displacement with maximum streamlining effect. The said air tunnel being very much flatter at the top in the following the countours of the underside surface of the said specially shaped overhead, upper unit. The capturing, streamlining, concentrating and thereby acceleration of the air of the said vehicle's air passage causing maximisation of it's forward kinetic energy content in accordance with the equations:— K.E.=$\frac{1}{2}\rho V^2$; V & 1/Area of said Turbine entry; P +$\frac{1}{2}\rho V^2$=Constant. The latter being the basis of the Bernoulli's theorem governing air streamlining by a moving body. The main basis of the concept thus being that there is a large advantage to be gained in the said forward kinetic energy of a given volume of displaced air of the said vehicle's air passage by an increase in the velocity, V of the said air due to the V^2 relationship in the aforegoing equations, which will be in excess of the air resistance of the said vehicle, the latter because of the said diminution of rear drag forces being less than normal. The intention also being to use the hollow nature of the said overhead, upper unit for the purposes of housing components of the said propulsion system such as generator and batteries.

3. A vehicle in which the system of Claim 1 is achieved by means of initially cleaving the air of the said vehicle's air passage with the front nose of the vehicle, forming an upper and lower air flow, which are then streamlined over both the upper and lower surfaces of the said vehicle's main body, respectively. The shape of the said main body of the vehicle in which driver and passengers would be seated, in this case being that of a full tear drop design in the length cross section, with the largest end being at the front of the said vehicle. The two separated air flows therefore initially diverging and then converging over the said respective upper and lower surfaces of the said vehicle. Then finally combining just prior to entry of the said air flows into said air turbine system of Claim 1. The said main body in this case being suitably contained within an outer structure comprising an overhead, upper canopy unit; a lower ground unit, the lower surface of which being parallel with, but several inches above, the ground; and side walls, with the creation then, in effect, of two similar shaped and sized air tunnels above and below the said vehicle's main body, which in vertical dimensions first decrease fairly rapidly over the said large frontal end of the tear drop shaping and then, comparatively, gradually decrease over the narrowing end of the said main body tear drop shaping, before then finally combining. The dimensions of the said vehicle and said air tunnels also gradually decreasing in the lateral plane towards the rear of the said vehicle, with then an optimimum sized area in the horizontal plane for the said combined air tunnel being formed just prior to entry of the said combined air stream into the said air turbine system of Claim 1. The latter also being of a corresponding optimum size. The said upper, overhead unit having it's upper surface fairly parallel with the ground, although probably slanting downwards slightly from front to rear, in contrast to the lower surface of said overhead unit which follows more closely the steeper slant of the said tear drop shaping towards the rear of the said main body. Similalry, the said lower ground unit being so shaped. Thus each of these said units will increase in vertical dimension towards the rear of the said vehicle with the creation of hollow spaces, which would be used for housing components of the said propulsion system such as generator and batteries, as being similarly the case in the said vehicle of Claim 2.

4. A vehicle in which the system of Claim 1 is achieved by having a smaller, but similar inner unit to that of Claim 3, but which in this case just the driver and perhaps one adjacent passenger would be seated, contained inside and more towards the front of an outer structure. This said outer structure comprising a similar said overhead upper canopy unit and said side walls to those of Claim 3, but in this case having a much larger lower unit in vertical dimension towards the rear of the said vehicle, which would seat passengers as well as house components of the propulsion system, e.g. batteries, as in Claim 3. The upper unit also being used for this latter purpose, similarly as in Claim 3.

5. A vehicle in which the system of Claim 1 is achieved by means of initially capturing and then streamlining all of the air of the said vehicle's air passage beneath the lower surfaces of the main body of the said vehicle, in which driver and passengers would be seated, with a lower ground unit, the upper surfaces of which form, in effect, a streamlining air tunnel with the lower surface of the said main vehicle body and side walls. This said vehicle therefore being the upside down version of the said vehicle of Claim 2, with respect to the streamlining of the air of the said vehicle's air passage. Thus similarly, but the other way around, the said air tunnel decreases from the full height of the said vehicle as the tunnel follows the contours of the lower surfaces of the said main body of the vehicle firstly more rapidly then more gradually, to optimum dimensions at the entry to the said turbine system of Claim 1, positioned towards the rear of the said vehicle. The lateral dimension also gradually decreasing from front to rear to yield the said optimum dimensions. The said lower ground unit will have it's lower surface several inches from the surface of the ground, which will be virtually parallel with the said ground, whilst it's upper surface will be suitably shaped for improved streamlining, probably of a shallow convex curve shape. The space thus created within the said lower ground unit being used to house components of the said propulsion system, such as possibly batteris and generators, as in the case of the upper, overhead, unit of Claim 2.

6. A vehicle in which the system of Claim 1 is achieved through the creation of two separate air streams by the said venicle's body in order to capture the whole of the air of the said vehicle's air passage, there being a lower and an upper air stream with each having their own separate said air

turbine and generator systems, in contrast to the said vehicles of Claims 2, 3, 4, and 5. The said lower air stream being formed at the lower front of the said vehicle by means of the creation of a short air tunnel, extending the full width of the said vehicle at the front, and extending several feet into the front of a vehicle, decreasing in lateral and vertical dimensions to optimum dimensions at entry into the said lower air turbine system, also of corresponding optimum size. This said lower system thus being in the position where the engine of a more conventional road vehicle would normally be placed, with the associated said air flow in this case exiting from the said lower air turbine system beneath and almost halfway along the lower surface of the said vehicle's body. The said upper air stream being created in a very similar fashion to that of Claim 2, with overhead, upper unit and side walls, but in this case, there being only about half the air of the said vehicle's air passage pass via this said upper air stream flow, the remainder passing via the aforementioned lower frontal system. Similarly, as with said previous vehicles, the spaces created inside upper and lower units being used to house components of the propulsion system such as generators and batteries.

7. Where applicable, the use of a frontal air scoop in the system of Claim 1, extending the full frontal width of the said vehicle(s) and extending as close to the ground as possible in order to then, firstly maximise the captured air of the said vehicle's air passage, and secondly to create a partial vacuum effect beneath the said vehicle---mainly for the purposes of application of the partial vacuum to the exits of the said air turbine systems, but also to improve upon road holding. This said frontal air scoop being a separate unit from the main body of the said vehicle, and being manually and semi to fully automatically liftable to the lower level of the said main body of the said vehicle(s).

8. Where applicable, the frontal shaping of the said vehicles of Claim 1, comprising upper and lower structures, being such as to create between them a venturi shaping entry in the intial approaches of the said air stream(s) to the said air turbine(s). The horizontal planar area dimensions of the venturi entry being close to, if not less than, the corresponding area dimensions of the said air turbine entry in order to then improve upon overcoming back pressure by the early attainment of maximised/optimum forward dynamic pressure in said air stream(s).

9. Where applicable, the use of suitably sized baffles, being tear drop shaped in the cross section, suitably positioned, inside and laterally across the said air tunnels of Claims 2—6 for the purpose of repeatedly speeding up the said air stream inside the said air tunnels on it's approach to the said air turbine systems. The said baffles, in conjunction with tunnel shaping, by said action further assisting in overcoming the back pressure and in maximising the forward speed of the said air stream in the steady state of the said systems, perhaps partially behaving as one way valves by said action. Furthermore, where applicable, the use of similar suitably sized tear drop shaped baffles across the front of said vehicles of Claims 2 - 6 to assist in early streamlining formation of the air of said air passages.

10. Where applicable, the use of suitably sized lateral vanes inside the said air tunnels and across the entry to the said air turbine systems of Claims 2—6, intended for the dual purpose of more sensitively directing the said air stream for maximising forward vector impingement pressure and to effect some final acceleration of the said air streams just prior to impacting into the impellors of the said air turbines. Similarly, for said dual purpose, where applicable, the use of an upturn shaping and possibly a corresponding downturn shaping at the end of the said air tunnels of Claims 2—6, on the lower and upper surfaces respectively, just prior to said air turbine entries.

11. The use of either a single or a dual stage turbine arrangement in the said turbine system of Claim 1. The dual stage arrangement comprising a primary turbine in the pathway of the said air stream closely followed by a secondary stage, being suitably linked to each other and to the said generator to effect it's rotation. The said primary stage being only that present in the said single stage arrangement and the turbine design therein being of either axial or a radial type, as also the units at both the said primary and secondary stages of the said dual arrangement. In the latter arrangement, the linkage between the said two stages and the said generator being effected by either a direct pulley link between the two stages with then a single pulley to the said generator shaft, or by separate pulley, or rod connections from the shaft of each of the two said turbine stages to the said generator shaft, with the gearing ratios being at an optimum for these said arrangements. The said linkages and said generator being so positioned as to cause as little impedence to said air stream flow as possible in accordance with Claim 1. The said secondary stage in the said dual arrangement being of either an air turbine, an air displacer, or a combination of an air turbine/air displacer, as the principal function of the said secondary stage

12. In the case of said axial unit designs being employed, the use of either one such unit or two similar said units side by side, in order to then take better advantage of the width of the said vehicles of Claim 1, applicable to both the said single stage or said dual stage arrangement as given under Claim 11. There being appropriate circular shaping of the said air tunnels in the approaches of the said tunnels to the said air turbine systems, in order to correspond to their axial entry shapes.

13. The said air displacer function, using an appropriate unit or units in the position of the said secondary stage of the said dual arrangement of Claim 11 and 12, being in order to principally effect removal of air from the rear of the said primary turbine(s), as opposed to acting in a turbine capacity for the principal purpose of capturing residual energy remaining in the air flow on exiting from the said primary turbine stage. Furthermore this said air displacer function being for the dual purpose of

maximising the pressure drop across the said primary turbine stage, whilst in the same action effecting more rapid replenishment of the said wake zone with air at the rear of the said vehicles of Claims 1—6. thereby improving upon the negation of said rear drag forces on the rear body of the said vehicles. Thus, in effect by this action, transferring and concentrating the said rear drag forces more directly just onto the rear of the said primary turbine stage, and in so doing, having the effect of also increasing the potential for energy conversion by the said primary turbine stage, in addition to the aforementioned action of minimising said rear drag forces on the body of said vehicles. The desired relative rotational speeds between the said two stages of the said dual arrangement being achieved by appropriate linkage and gearing ratios, using either of the said linkage systems of Claim 11, and their inter-connecting actions being such that the rotation of one stage effects the rotation of the other and vice versa, as well as the said generator. There being two principal ways of applying the said dual arrangement, firstly by having the air displacement capacity of the said air displacer stage grater than the volume of air flow entering and passing through the said primary turbine stage, thereby by this means also creating a partial self sustaining interaction between the said two stages in which, in the steady state of the system, the forward air velocity of said entering air stream becomes maximised, leading to maximisation of energy conversion, as well as ensuring said maximum pressure drop across said primary turbine stage and maximised immediate said wake zone replenishment with said exiting air, as in Claim 1. Secondly, by having the air displacement capacity of the said air displacer stage the same or slightly less than the volume of said air passing through the said primary turbine stage, and in so doing, intending to achieve some capturing of residual energy in the said air flow on passing through the said primary stage by special design of air displacer, as well as also aiding the passage of said air to the rear of the said vehicles in order to better replenish the said wake zone and in so doing achieve some concentration and transference of the said rear drag forces onto the rear of the primary turbine stage. This said second action being the combined air turbine/air displacer function referred to as in Claim 11.

14. The use of a relative speed ratio adjuster between the said two stages of the said dual arrangement of Claims 11, 12, 13, in order to then effect ongoing optimisation of their relative rotational speeds according to vehicle speed, either by semi or fully automatic means. A method of achieving the latter being by a pre-programmed, on-board, computer relaying pre-determined settings electronically to the said speed ratio adjuster in response to said vehicle speed input.

15. In cases where applicable, the use of ducts extending the full width of the said vehicles of Claims 1—6 and creating connection between the said underside partial vacuum, as caused by the said frontal air scoop, and the said air turbine system, in order to then apply the said partial vacuum to the inter zone region between the said two stages of the said dual arrangements of Claim 13, for the purpose of maximising the said pressure drop across the said primary turbine and, therefore, the energy conversion potential of the said system. Similarly, the use of said ducting arrangements applied more directly onto the downward stroke of either the said primary stage, secondary stage, or both said stages in the respective systems of Claims 11, 12 and 13, with the intention of similarly achieving increased energy output. The underside floor shaping in said vehicles, being such as to improve the said partial vacuum, suctional, effect. For example, by having downturns on the underside front edge of the said ducts.

16. Similarly, and in cases where applicable, the use of upper ducting arrangements extending the full width of the said vehicles of Claims 1—6 and creating a connection between similar regions of the said air turbine system as those for Claim 15, and the rear topside surface of the said vehicle, thereby being exposed to the surrounding air. The suctional force in this case being created by the rapid flow of said surrounding air over a special hump shaping on the said rear topside surface, extending the full width of the vehicle and having the said exposed ducting at or near its peak. Similarly, for the purpose of maximising the energy output of the said systems of Claims 1—6.

17. The possible use of sliding covers in suitable combination with the said ducting arrangements of Claims 15 and 16 in order to then facilitate for variable adjustment of the said ducting's effective width, and thereby the effective said suctional force created by the said ductings, for the purpose then of optimising said suctional force for the rotational speed of said air turbines/air displacers, and the speed of said vehicles. This being achievable by a semi or fully automatic method, possibly by means of a choke type of adjustment mechanism or more electronically, perhaps again via a pre-programmed on-board computer, having predetermined settings relayed in accordance with monitored said speeds, as used in Claim 14.

18. As an advancement on more conventional designs, the possible use of special designs for the said air turbines in the systems of Claims 1—6, with respect to their impellors, particularly in said systems in which said radial turbine types are being employed, when it is considered the special properties of laminar air flow could be used to good advantage e.g. laminar layering, as follows:— (a) the application of lift and drag forces onto shaped impellors of a wing design, centrally fixed and possibly in combination with said entry vanes for improved direction of air flow: (b) similarly, the possible application of said lift and drag forces onto convex curved impellors which will also give increased surface area for the main impingement pressure: (c) the use of convex curved impellors

which are offset from centre and either overlap slightly in the central region or overlap up to halfway across, with the creation then of a void central zone in which a central convex of air will 'roll' up during use. Thereby probably improving upon the extraction of energy from the said air flow. This feature possibly being coupled with said effect given under (b); (d) a combination of (a) and (b) in which wing shaped impellors, slightly convex curved, are offset from centre so as to also create said central vortex in use. Thereby combining and maximising all the possible forces and effects that could result in improved extraction of energy from the said air flow. Possibly also in this case the use of underside flaps.

19. The possible use of a specially designed unit in the said second stage of the said dual arrangement given in Claim 13 for the purpose of performing the said dual function of air turbine for extraction of air flow energy and air displacer. This being achieved by the use of short impellors in the central region of a said radial design unit, in between full length impellors. The former being for the purpose of capturing said air flow residual energy and the latter mainly for the purpose of air displacement. The relative impellor rotational speeds at centre and periphery and the relative positioning of the said two stages being such that the periphery of the said air flow on exiting from the said primary stage, where most of the said residual energy is likely to be, will impact into the relative slower moving short central impellors, whilst the said larger impellors will mainly carry out the said displacement of air, being faster moving relative to the said air flow towards their periphery. This said special unit possibly being used in combination with said ducting arrangements, especially acting upon the downward stroke of the said primary stage.

20. The use of very friction free shaft bearings on the said primary and secondary stage units of the said air turbine systems of Claims 11, 12 and 13, with the possible use of continuous light oil drip feeds to the said bearings.

21. The use of aerofoil deflectors across the rear of the said vehicles in order to aid the exiting air from the said air turbine systems of Claims 11, 12 and 13, in the removal of said rear drag forces on the said vehicles bodies and to help direct the said drag forces onto the said air turbine system exits.

22. The possible use of an optimum number of smaller generators appropriately linked to the systems of Claims 11, 12 and 13, as opposed to the use of one larger generator, in order to then possibly lower the back pressure effect of the overall back EMF on the velocity of said air stream.

23. The possible use of a variable gearing system between the said air turbine systems of Claims 11, 12 and 13, and the associated generator system in order to then maintain a more constant and optimum said generator system rotational speed for a variable said air turbine system rotational speed. Thereby better achieving peak said generator system output performance over the range of said vehicle, and therefore said air turbine system, speeds, i.e. the maintenance of maximum torque equilibrium between applied said air stream force effecting forward rotation and the back retardation effect of the said back EMF. This inclusion possibly being a further function of an on-board pre-programmed computer, which electronically effected pre-determined said generator system speeds in accordance with said air turbine speed, similarly as employed under Claims 14 and 17.

24. The inclusion of a reserve second battery bank operating in conjunction with the said main battery system given under Claim 1 in order to then better maintain the battery electrical supply efficiency over a longer period of a journey in which energy usage exceeded energy production by the action of changing over to the said second battery bank at times when the efficiency of the said main battery bank become lowered due to a lowering charge on the said main system, and vice-versa. Monitoring of said battery efficiencies and the change over, possibly being another function of an on-board computer.

25. The possible inclusion of a change over system on the said generator system given under Claim 1 to facilitate for a direct feed electrical supply to the said electric motor system, with any surplus electricity being fed for storage in said battery systems, at times when the said generator system was producing more electricity than was required by the said electric motor system in use. Thus, by this means reducing energy losses due to inefficiencies of said battery systems.

26. The possible use of high impact non-breakable glass for the said vehicle bodies of Claims 1 - 6 and for various components of the said systems therein such as the turbine impellors, as an alternative to the use of more conventional materials.

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1/2b

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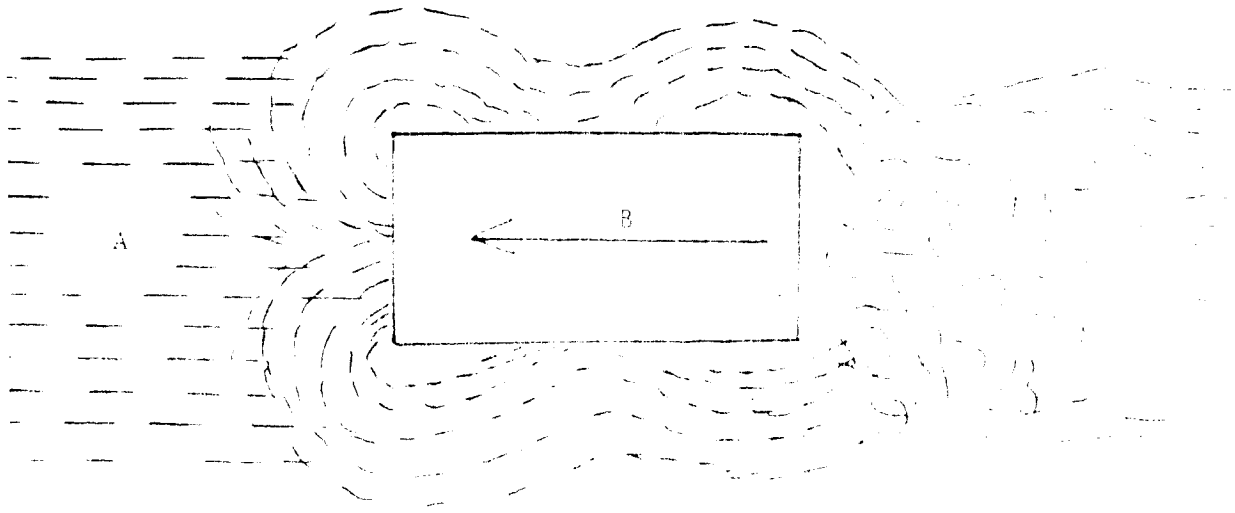

FIG. 1

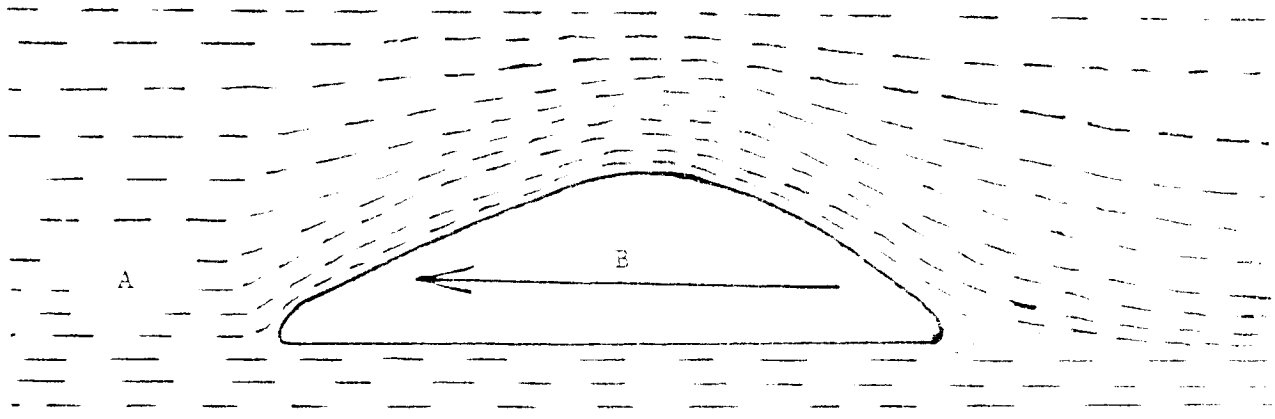

FIG. 2

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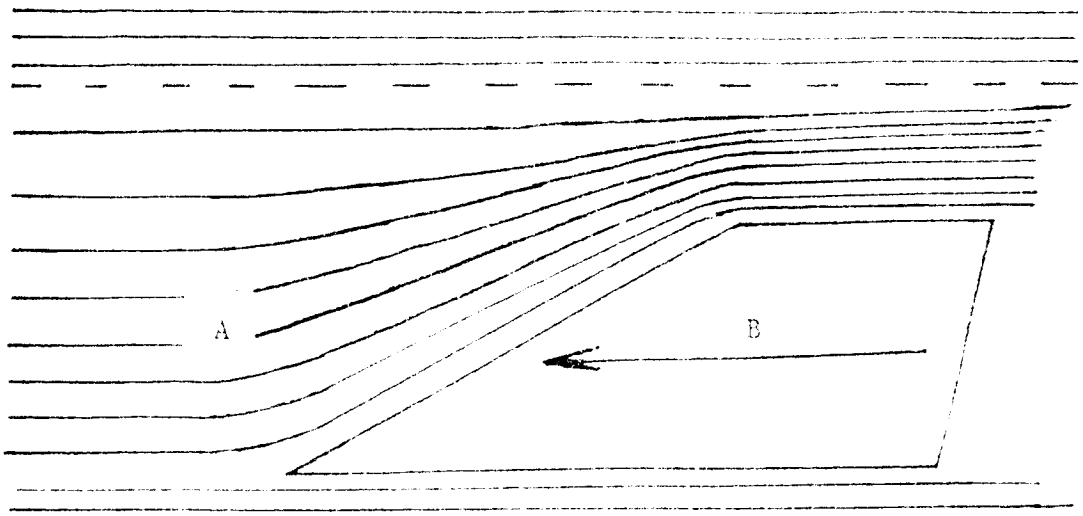

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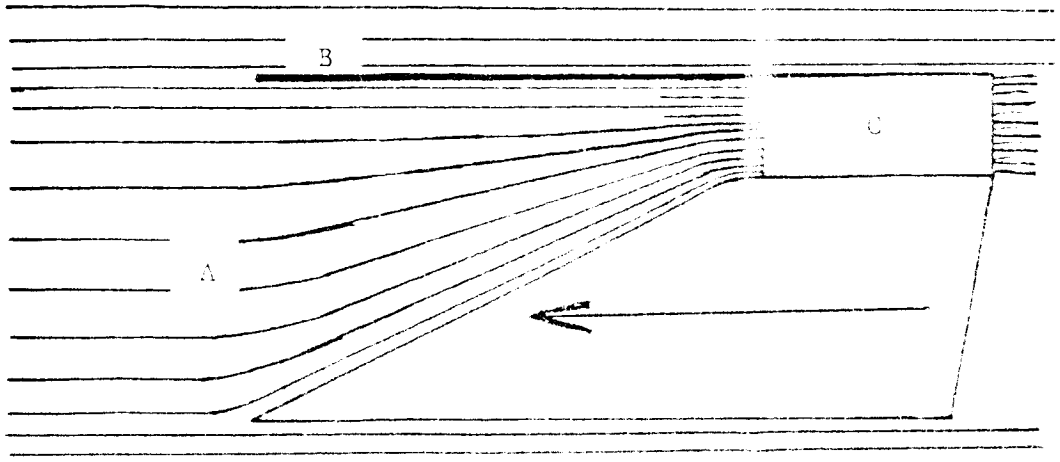

3/24

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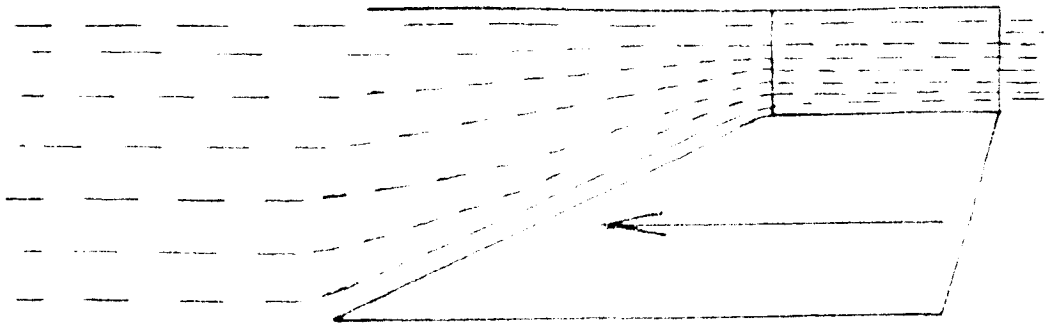

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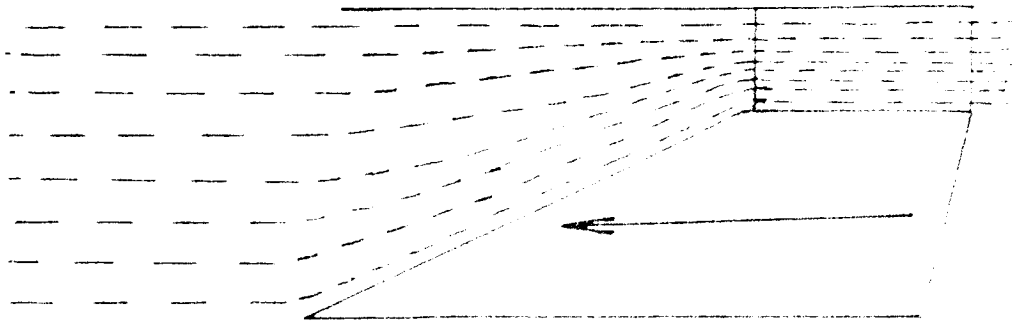

FIG.

5/26

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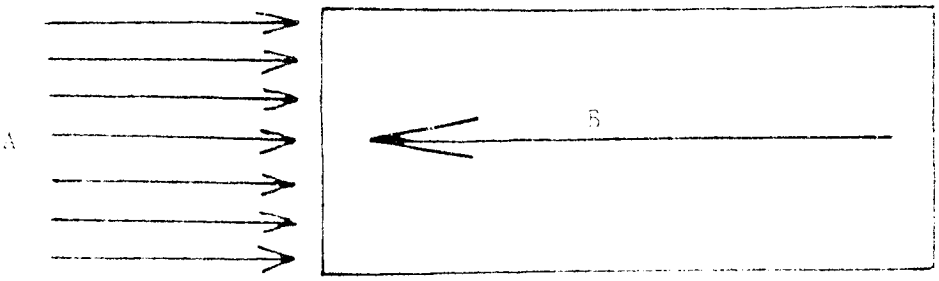

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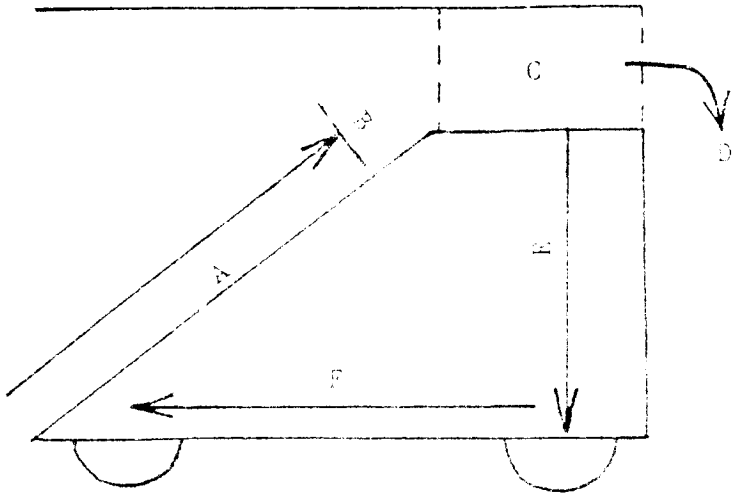

FIG. 11

6/26

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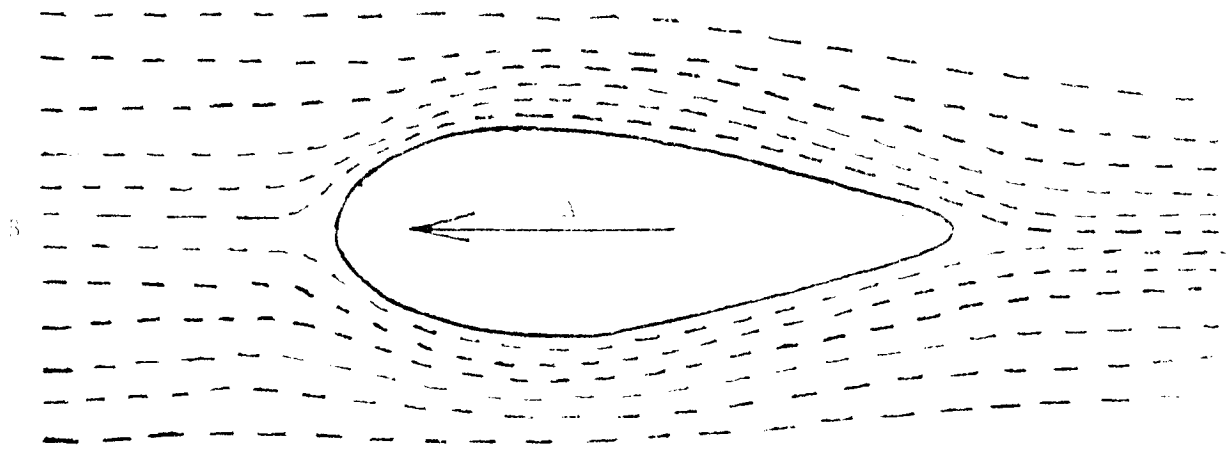

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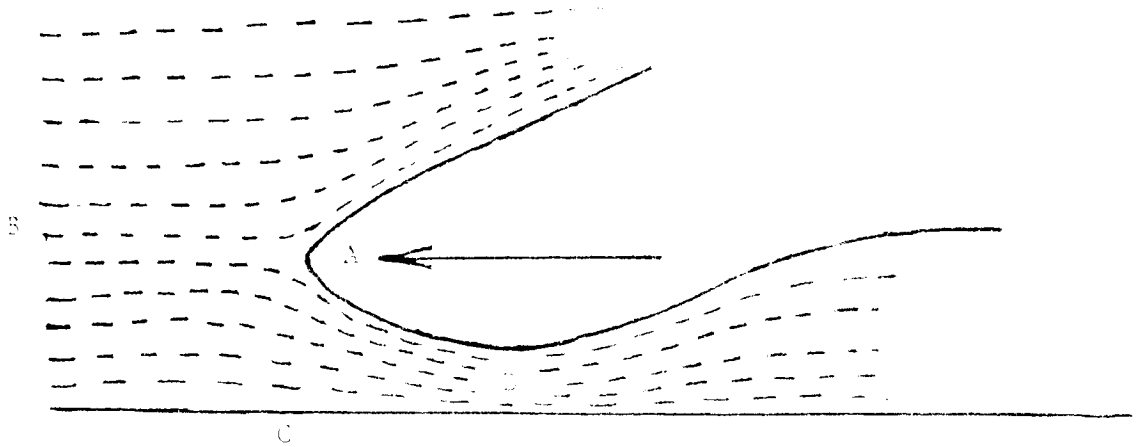

FIG. 13

7/26

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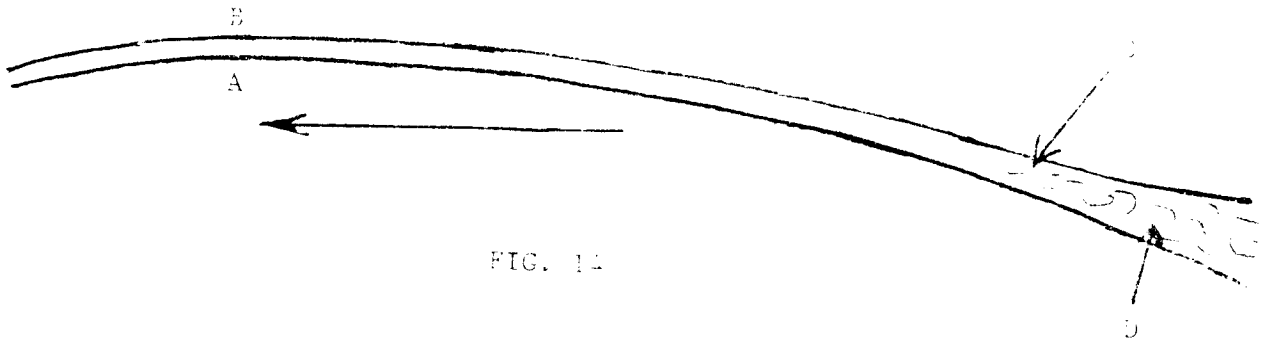

FIG. 14

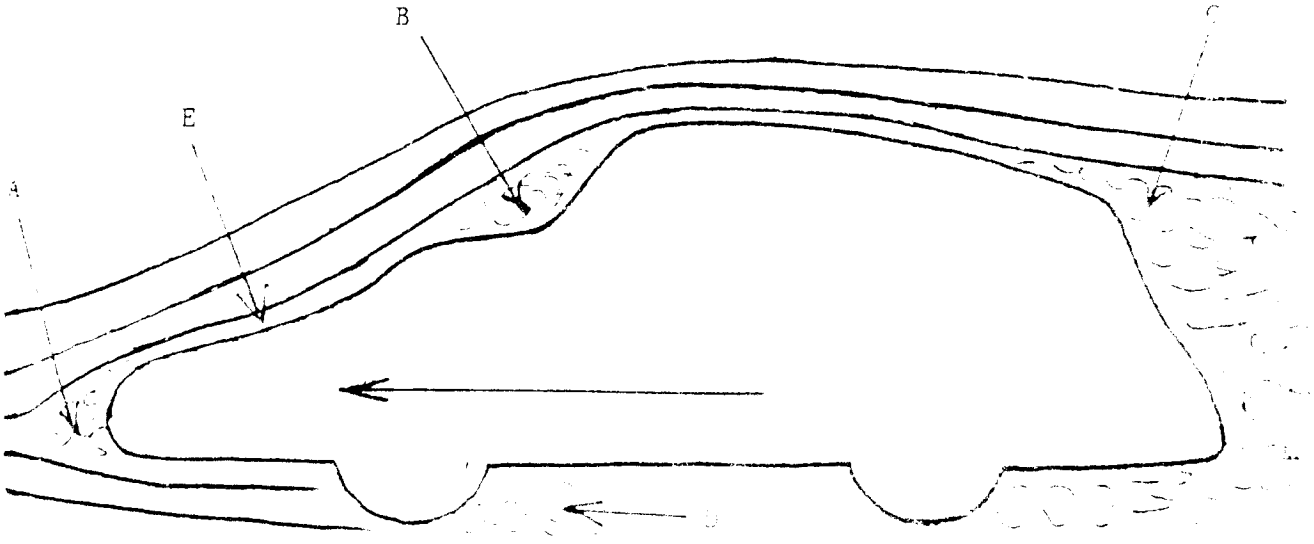

FIG. 1

8/26

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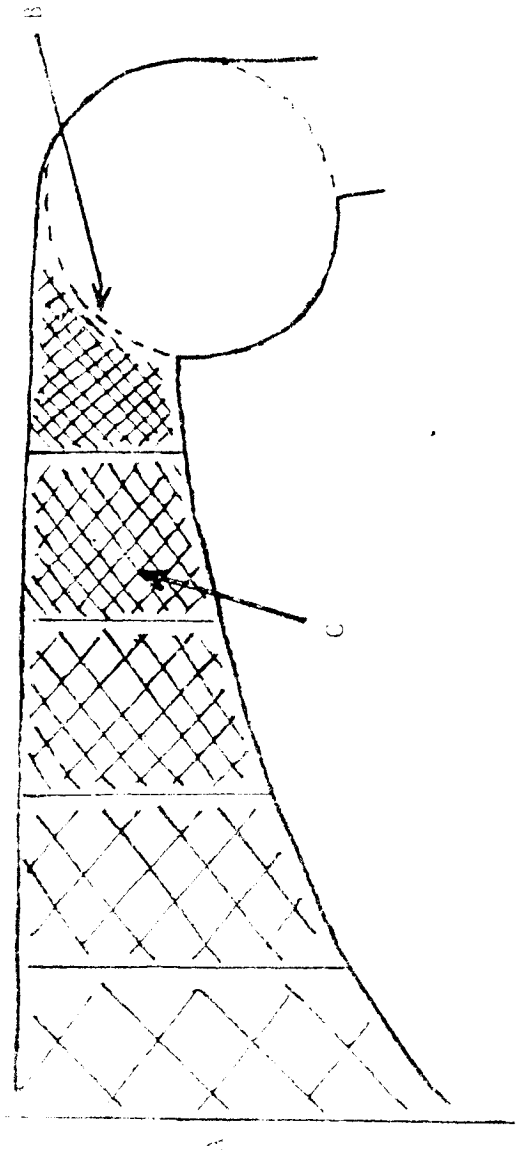

FIG. 16

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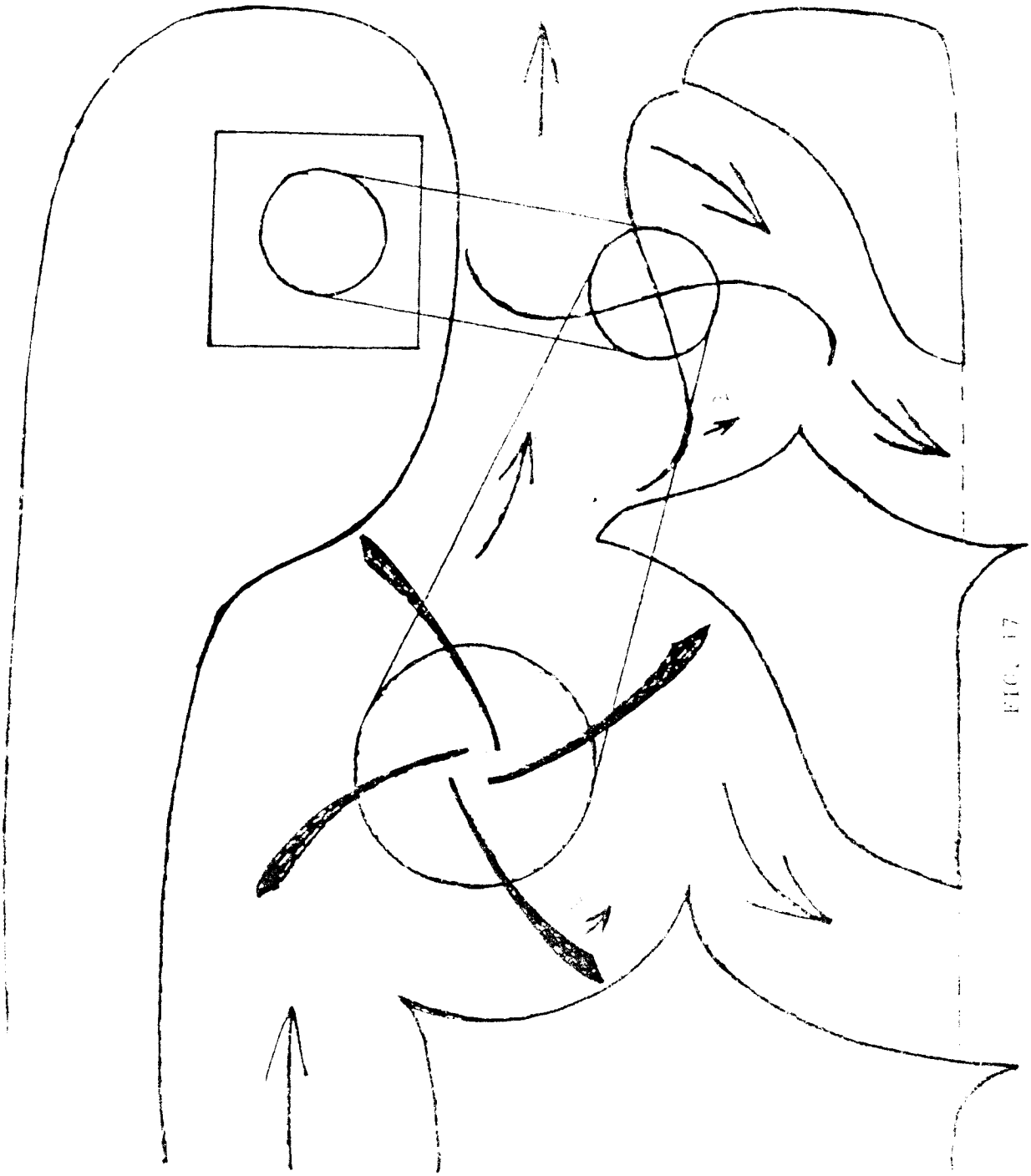

FIG. 17

10/26

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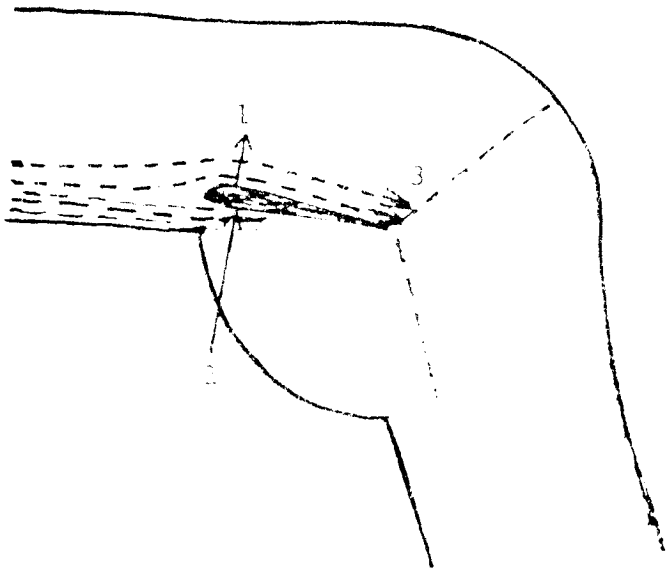

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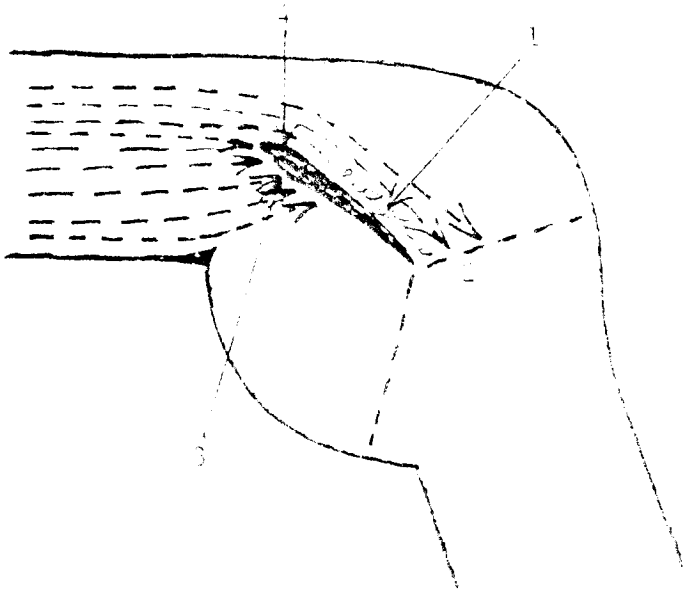

FIG. 14

11/26

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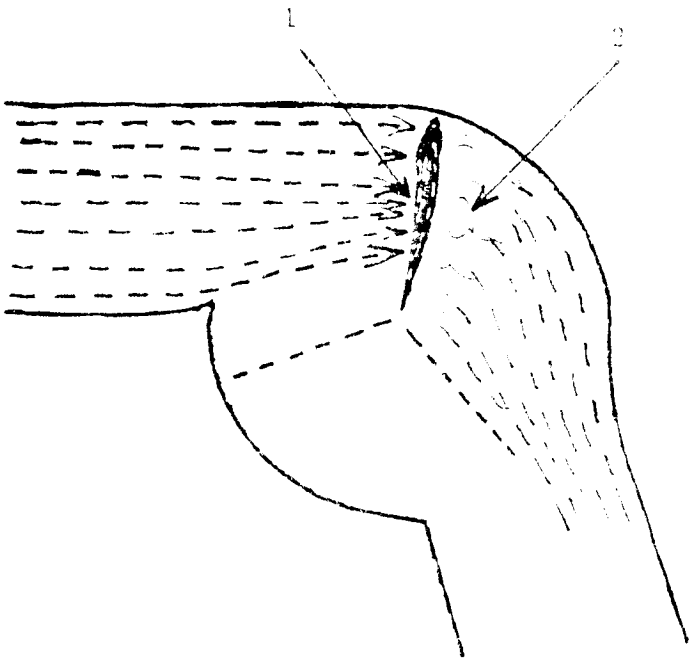

FIG. 20

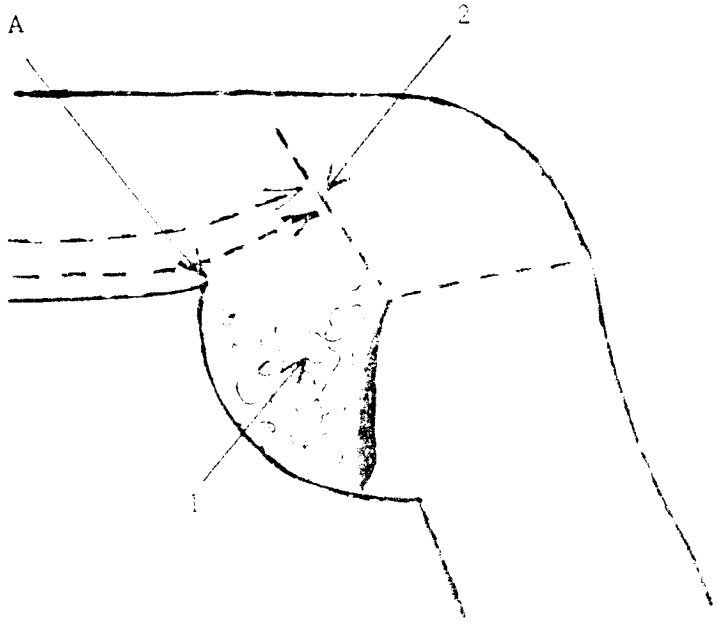

FIG. 21

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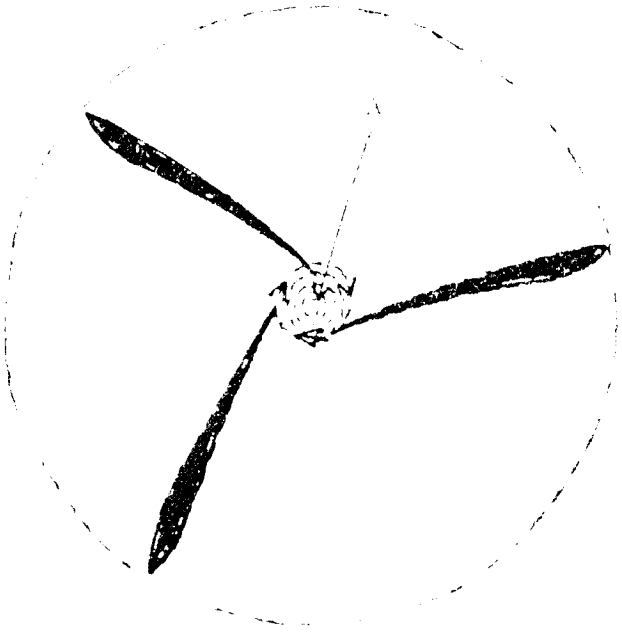
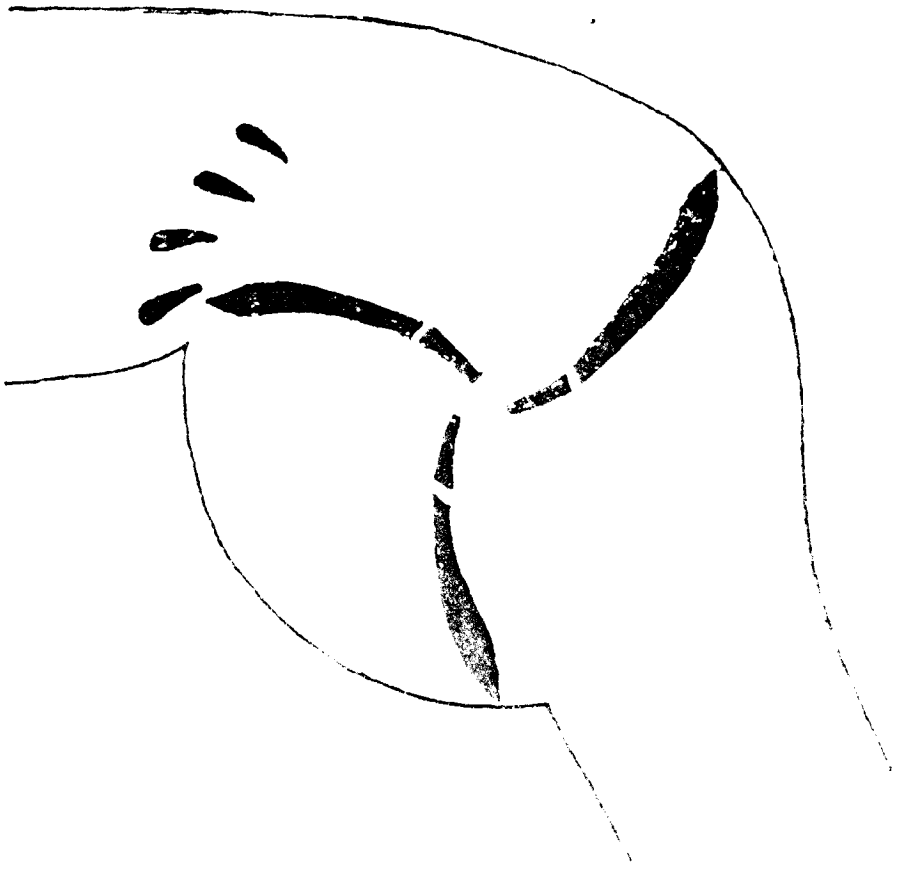
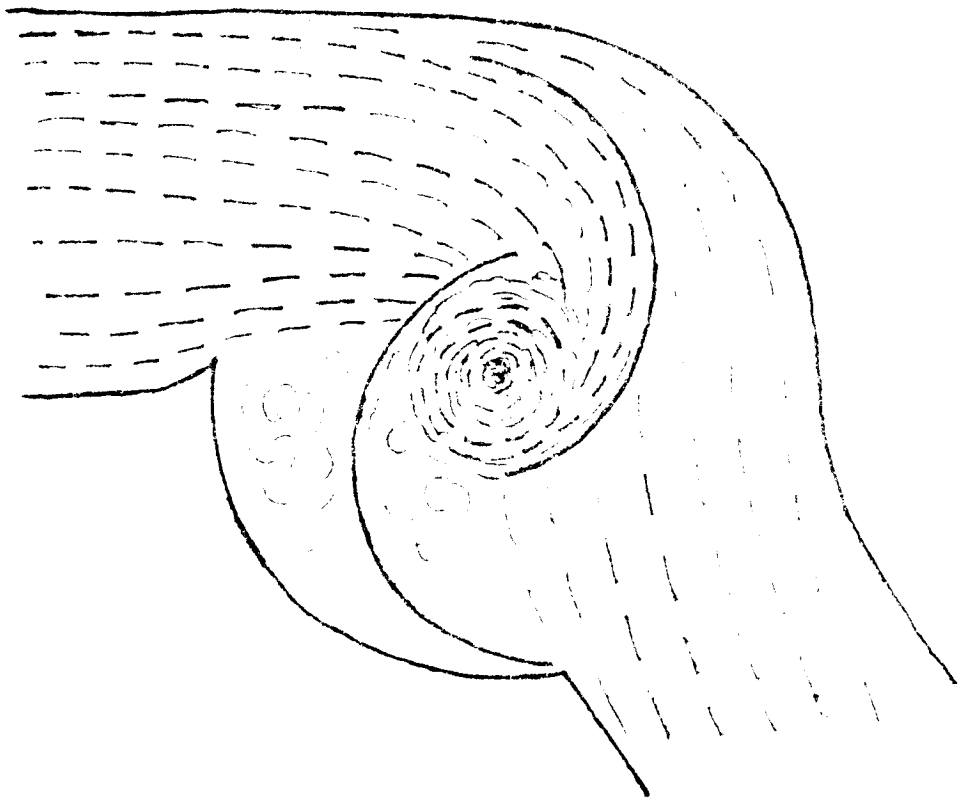


FIG. 22





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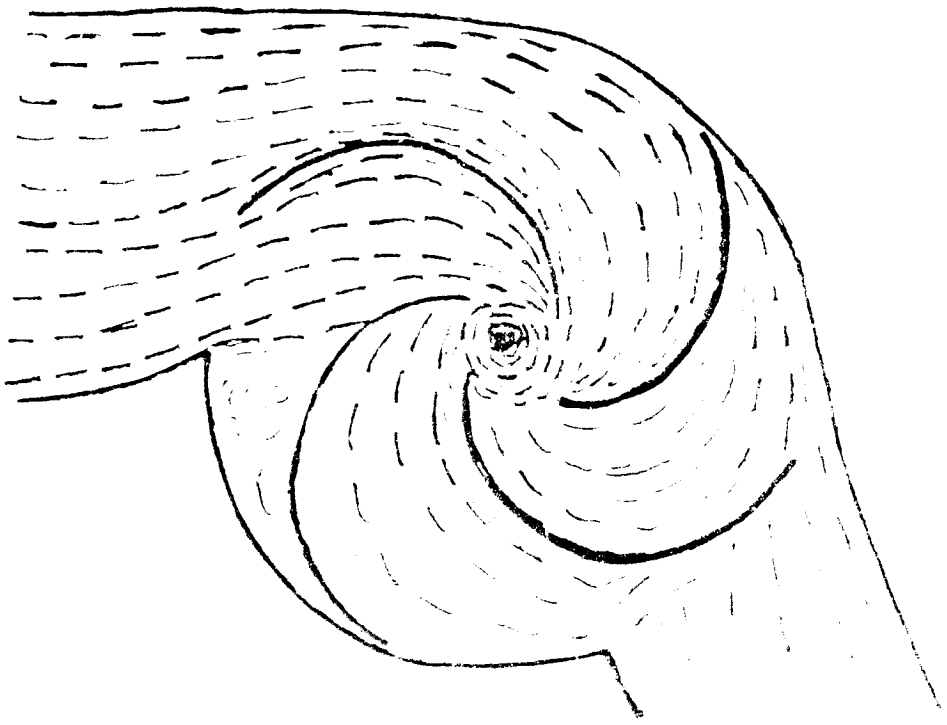

14/26

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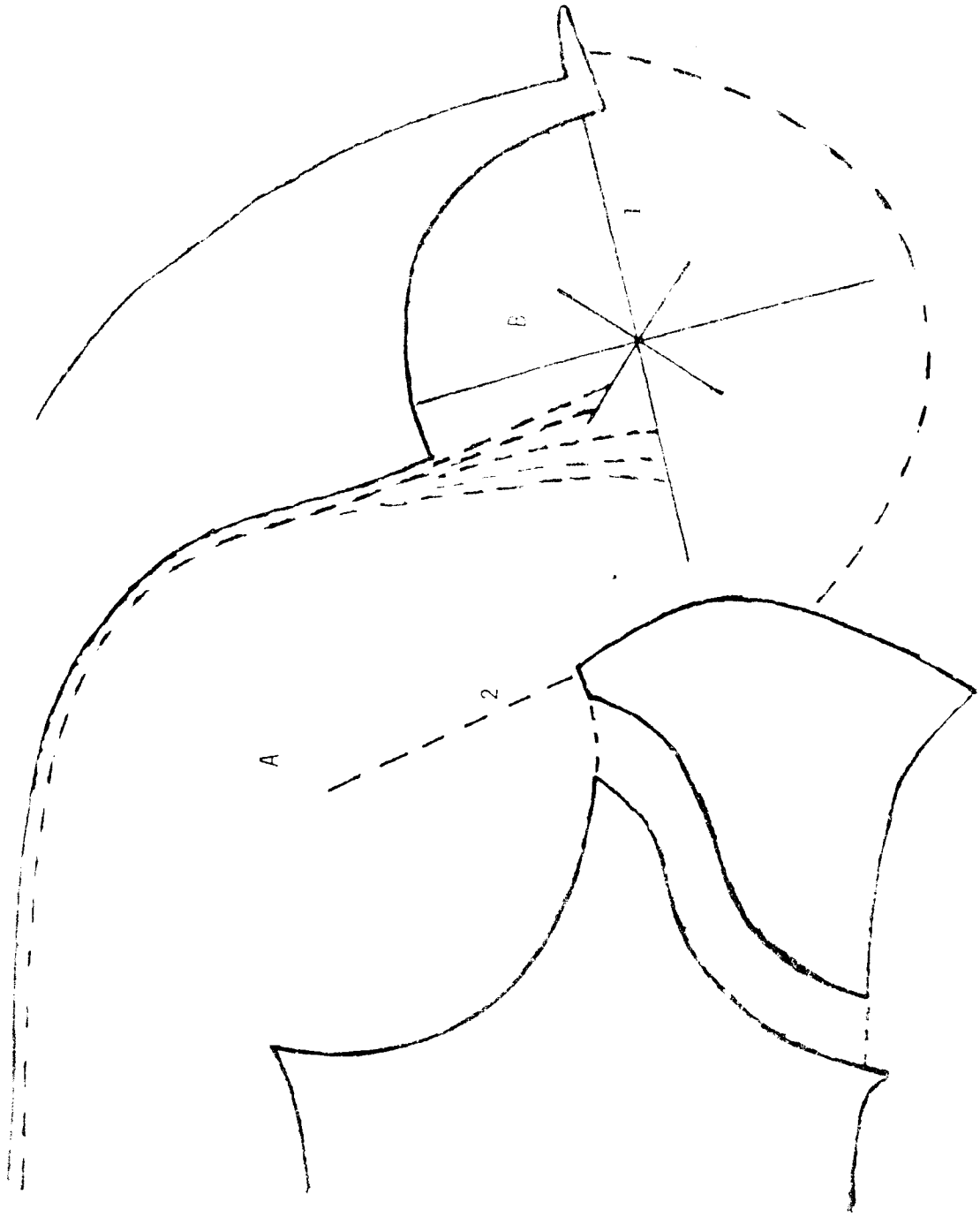

FIG. 26

15/26

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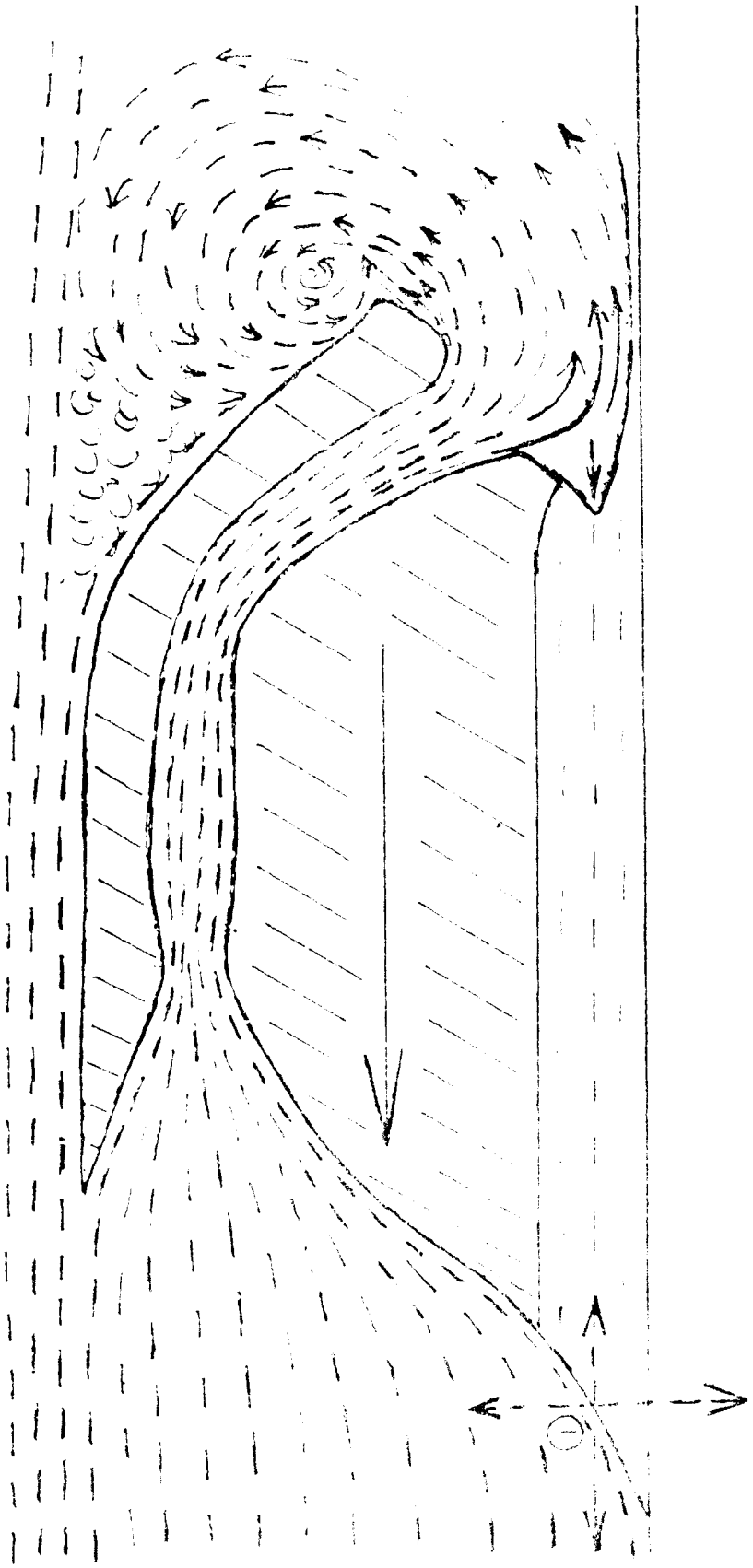

FIG. 27

SCHEMATIC DRAWING

16/26

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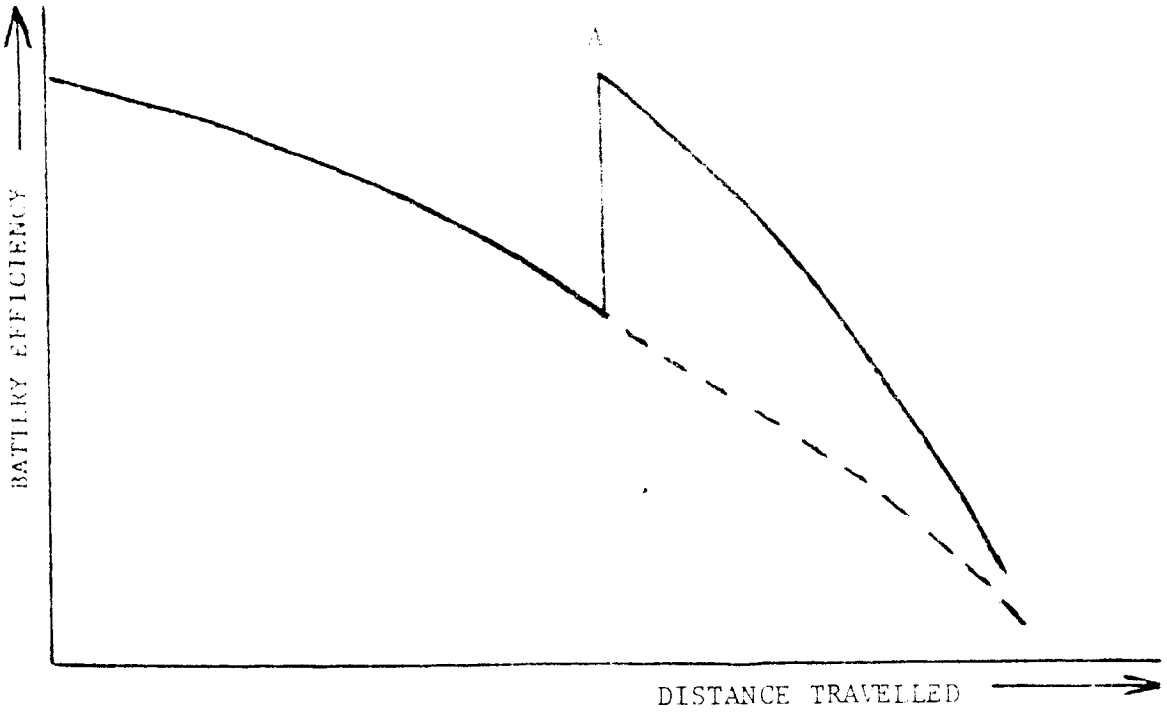

FIG. 28

17/26

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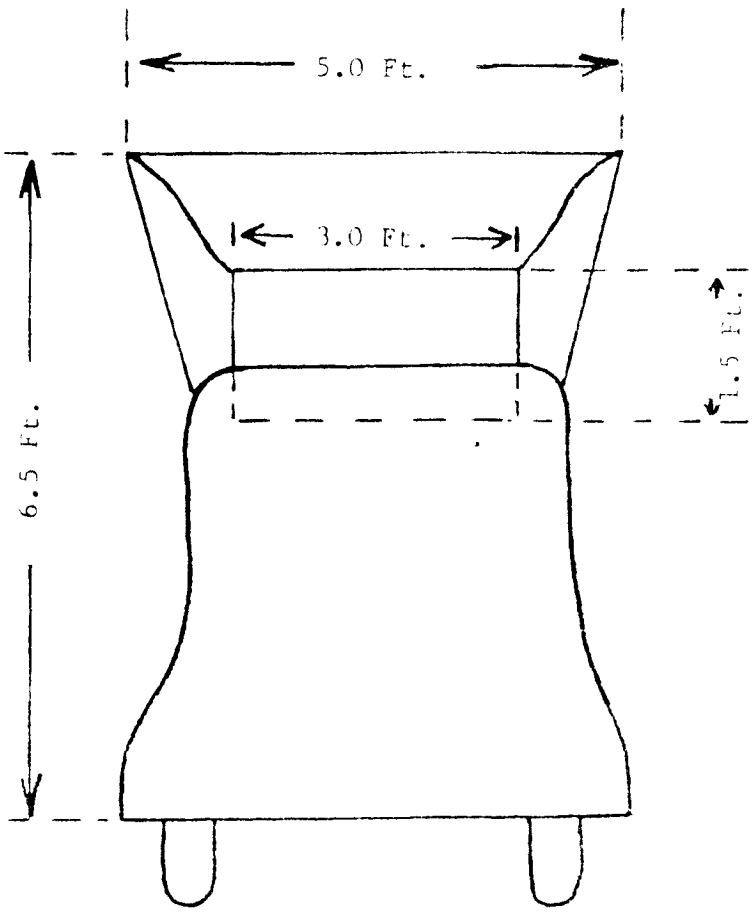

FIG. 29

18/26

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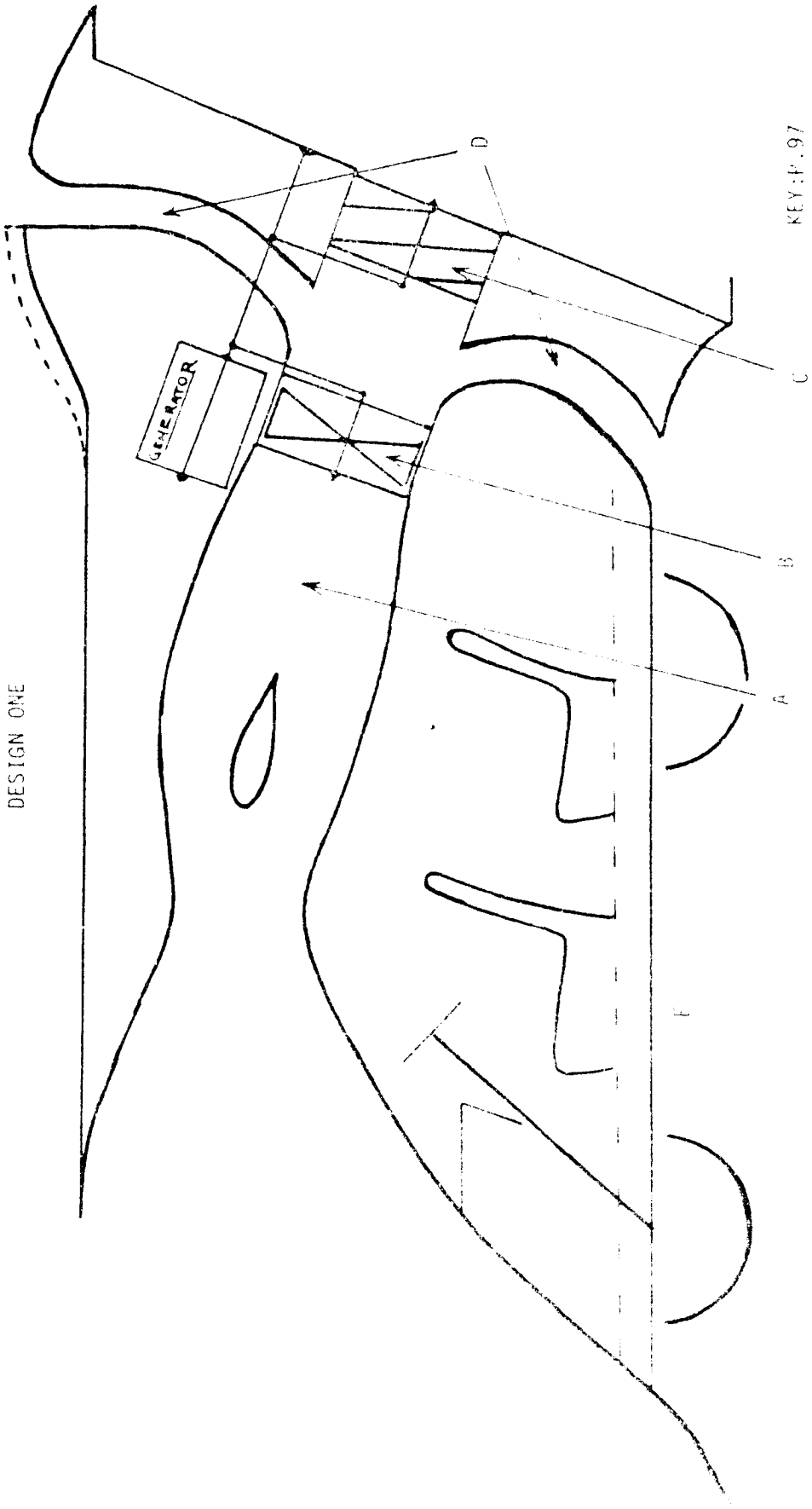

115

DESIGN ONE

19/26

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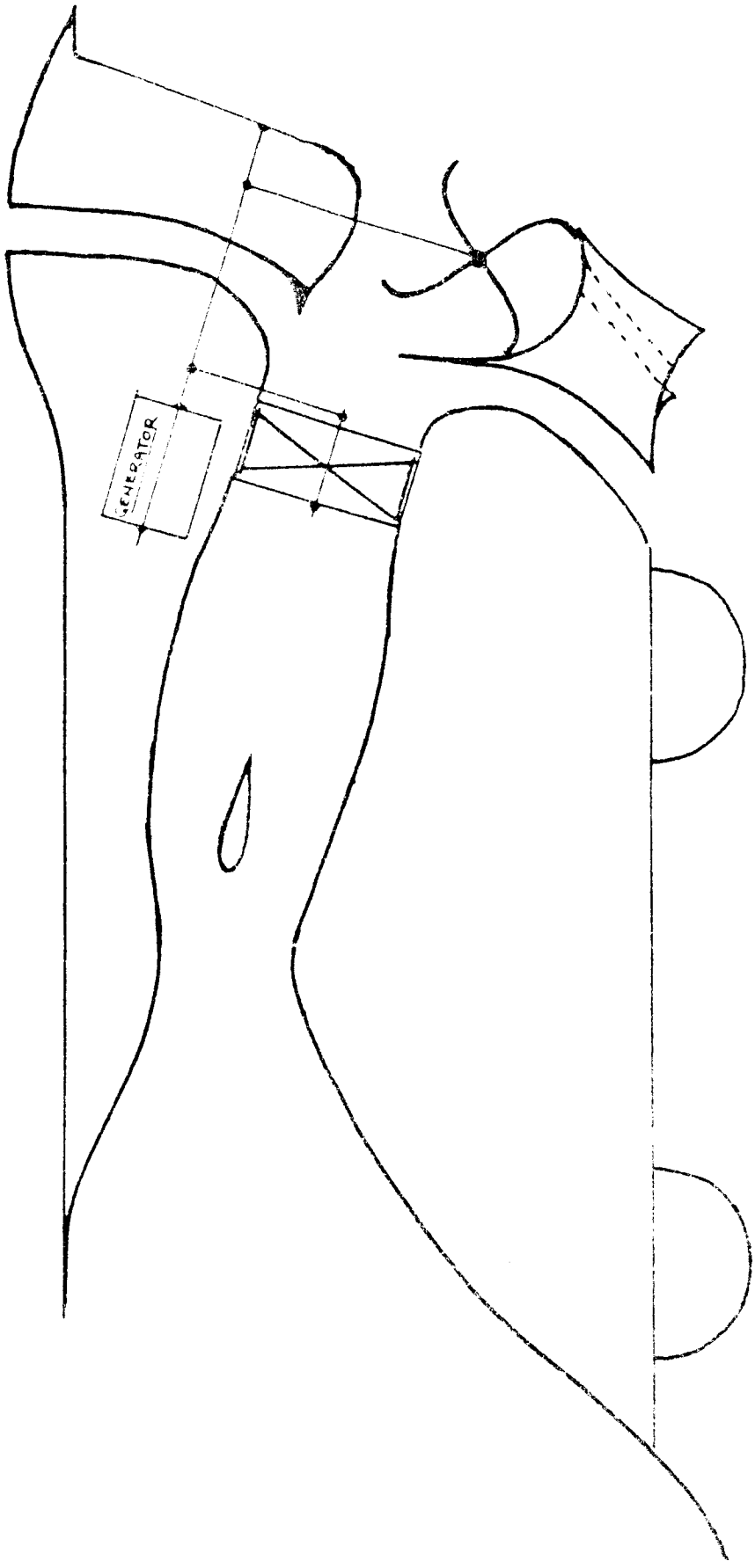

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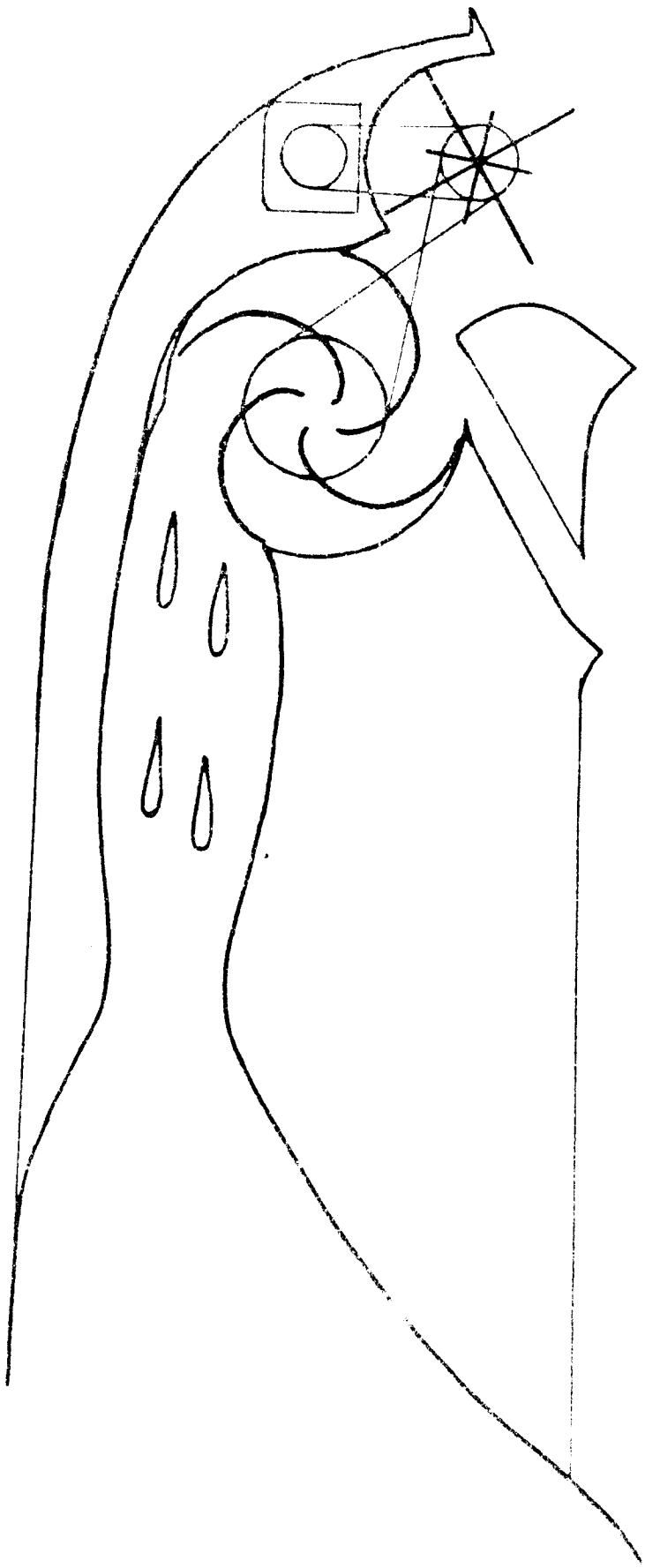
DESIGN TWO



117

DESIGN THREE

21/24

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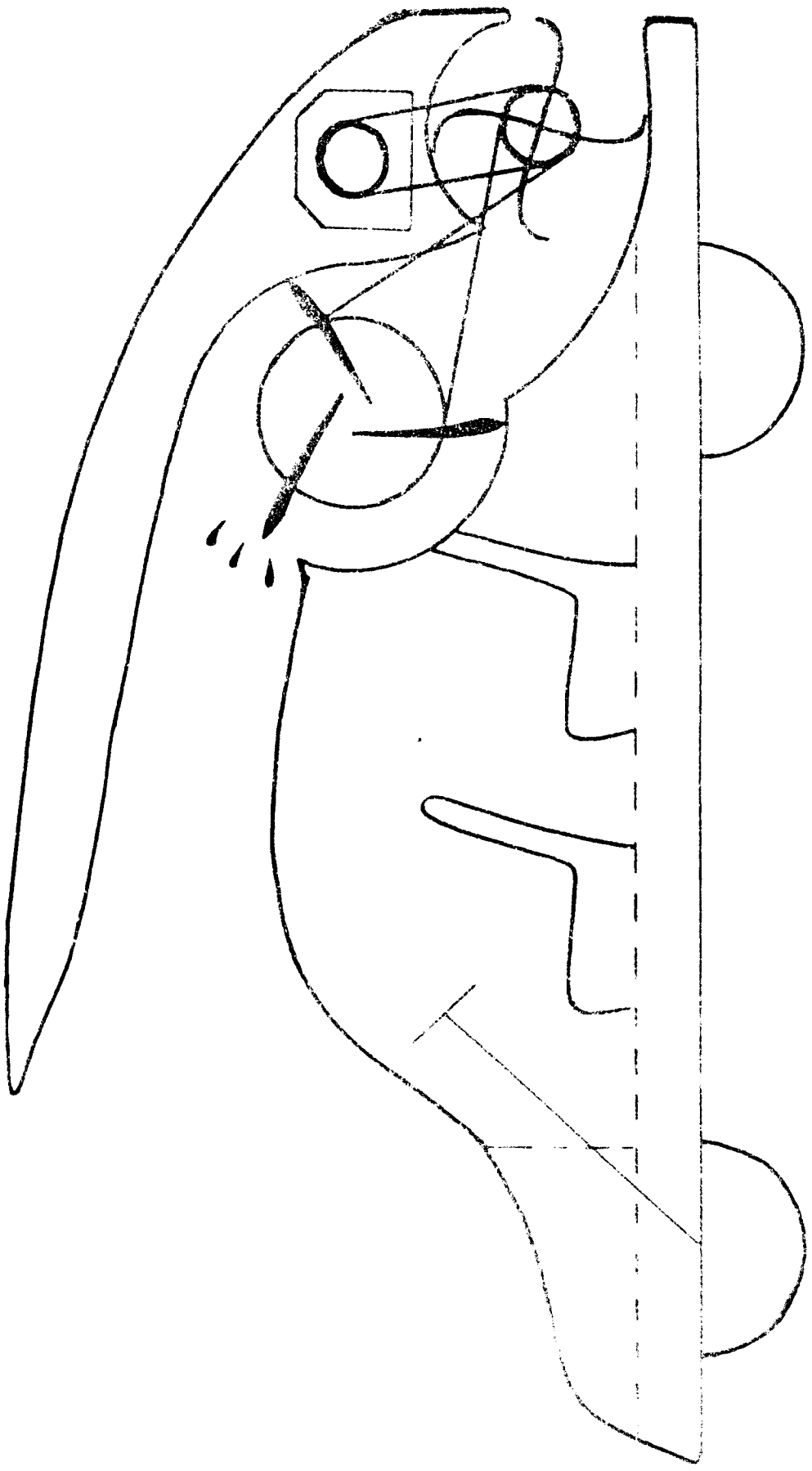

DESIGN FOUR

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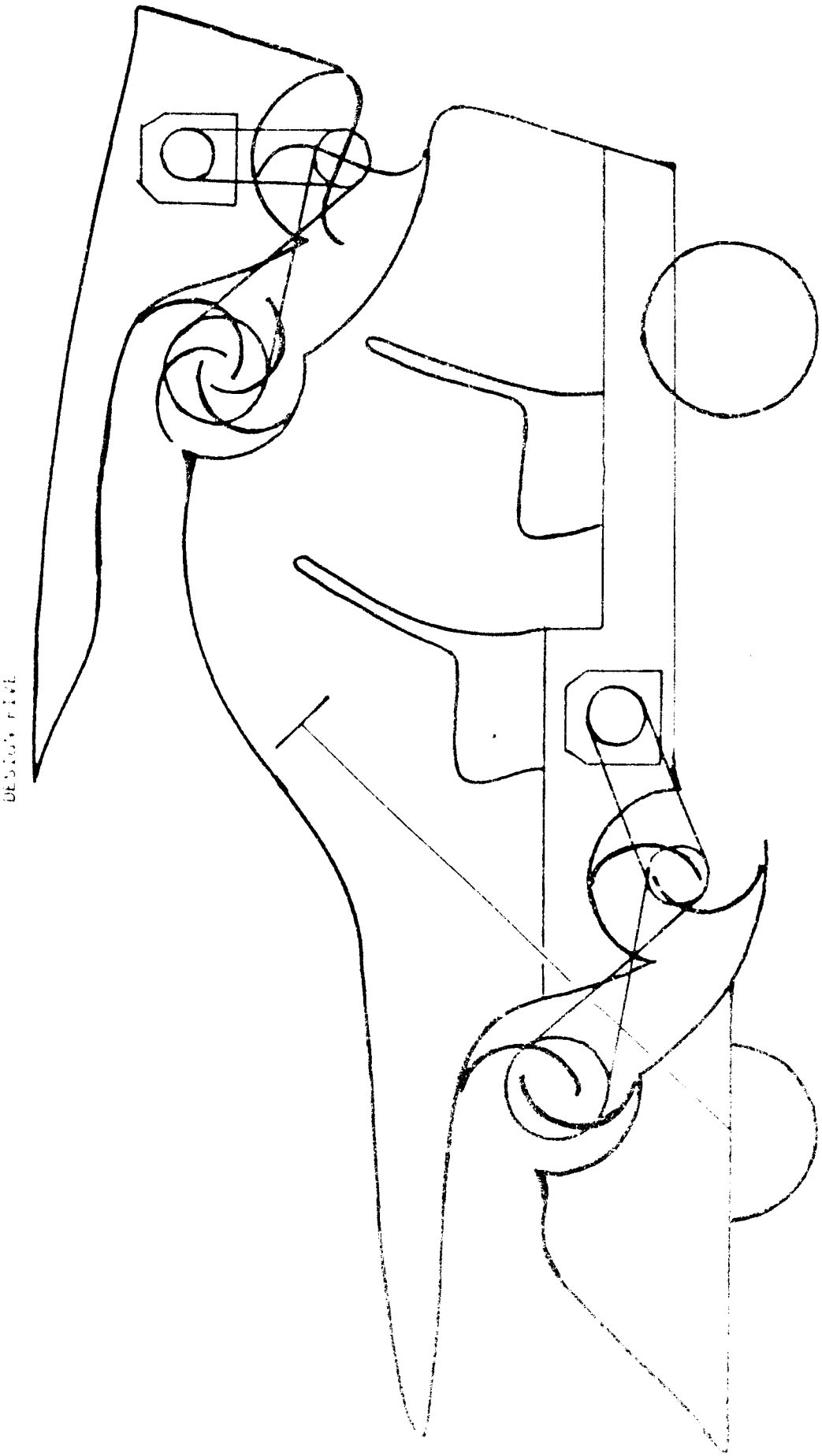

23/26

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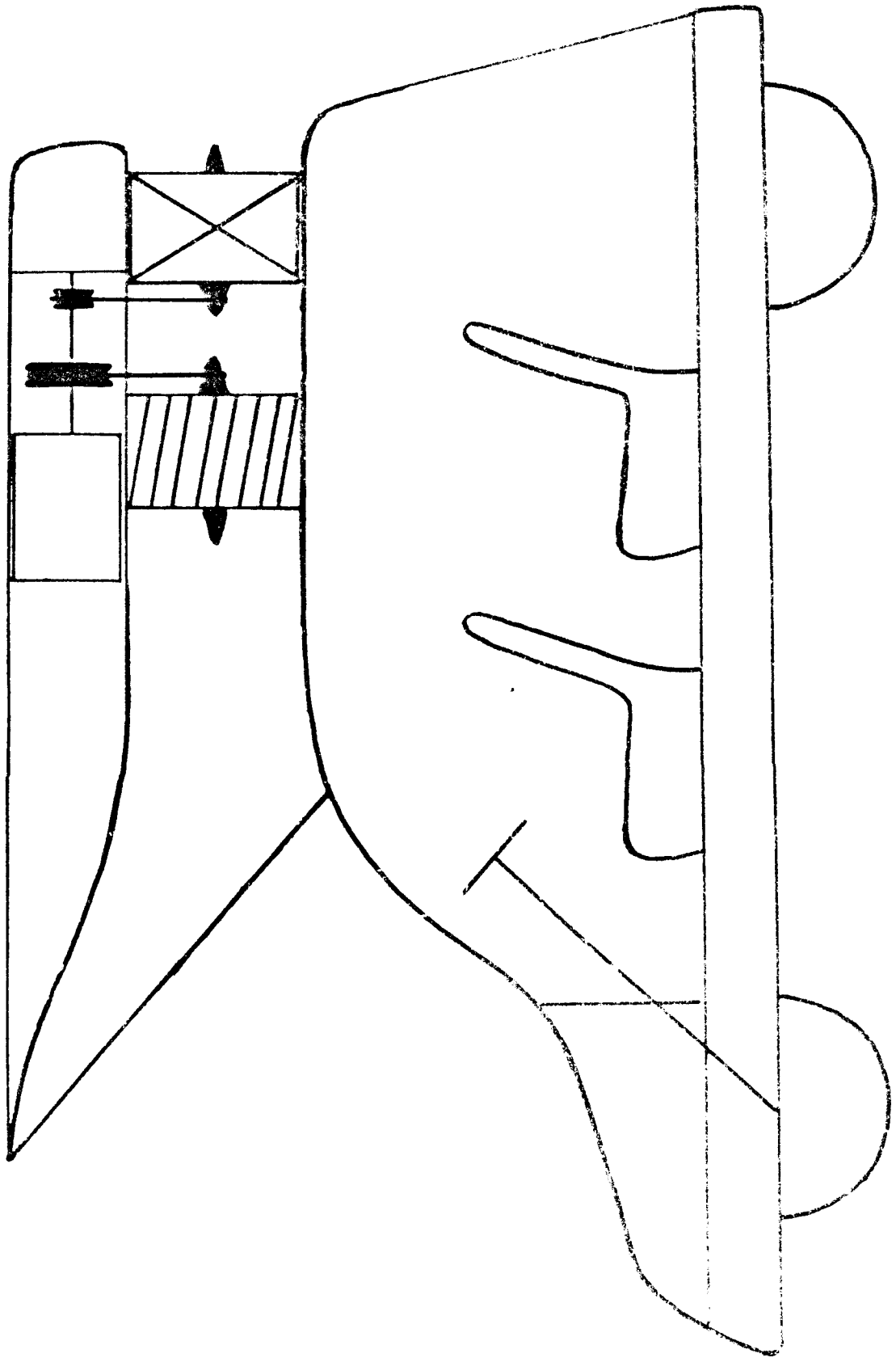

DESIGN SIX

24/26

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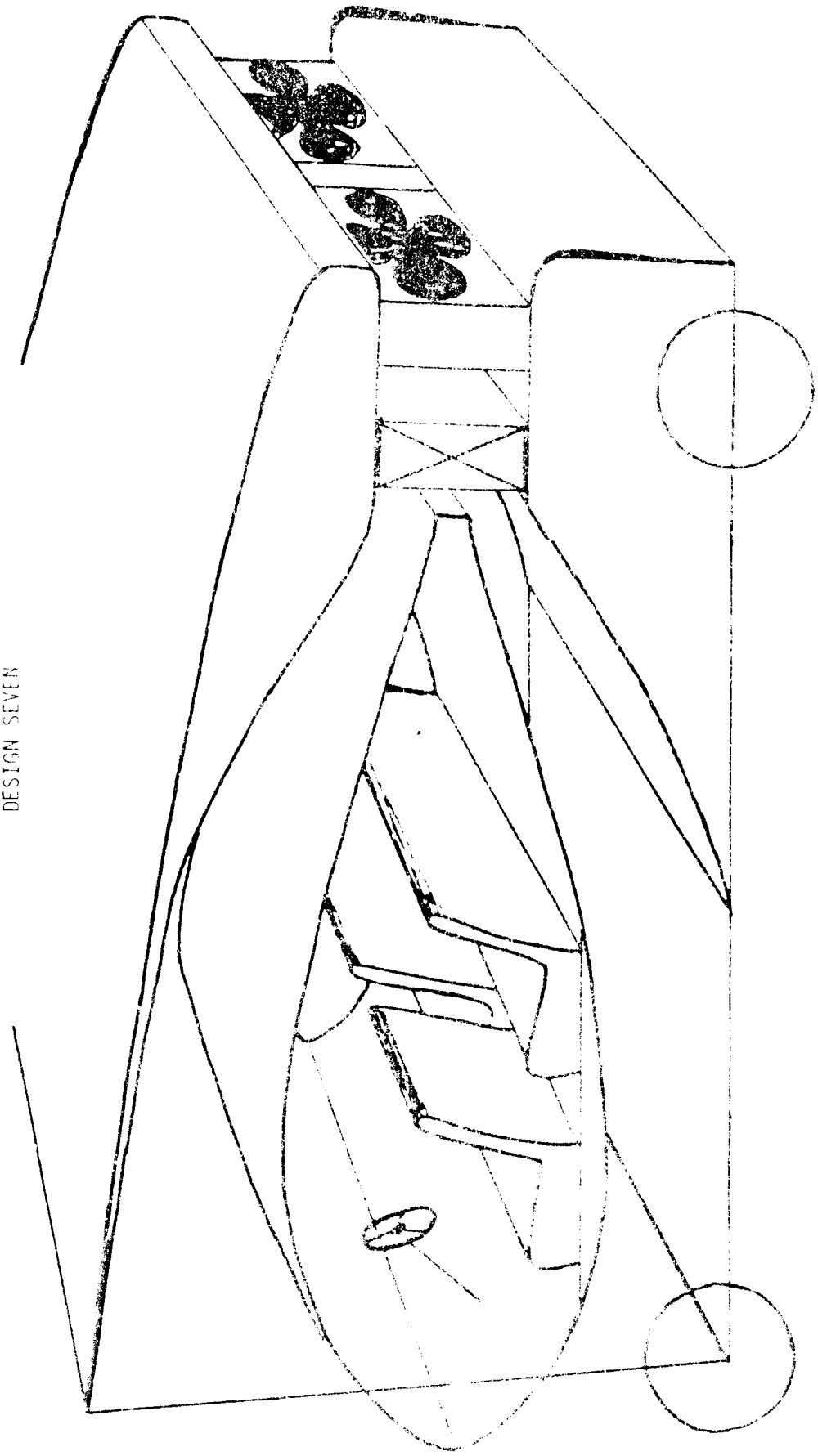

121

DESIGN SEVEN

25/26

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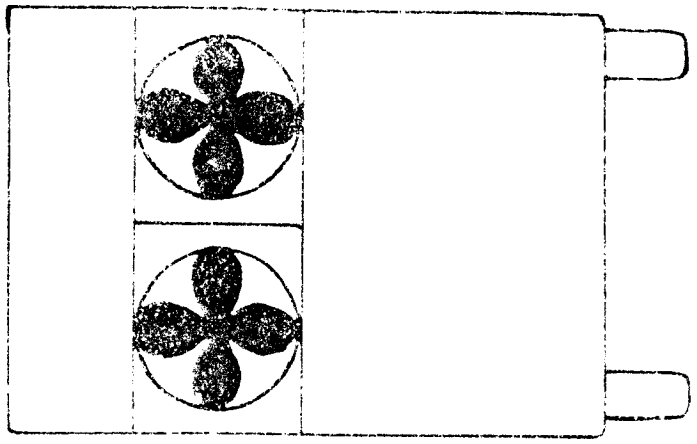

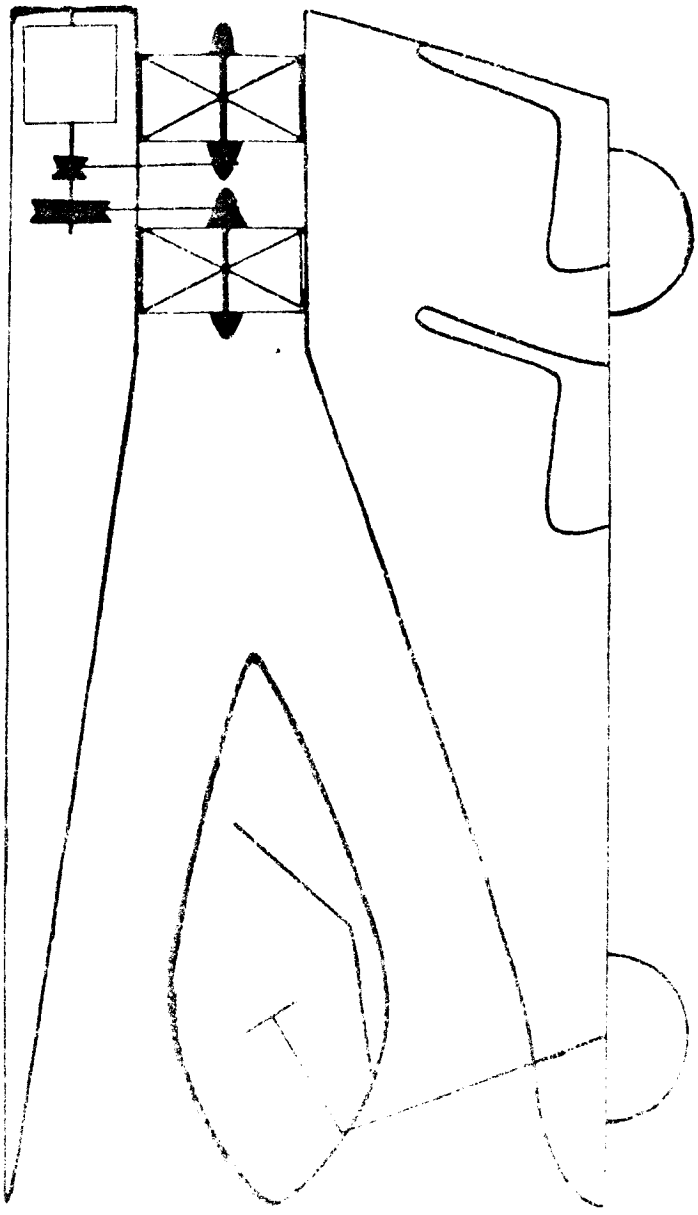

122

DESIGN EIGHT

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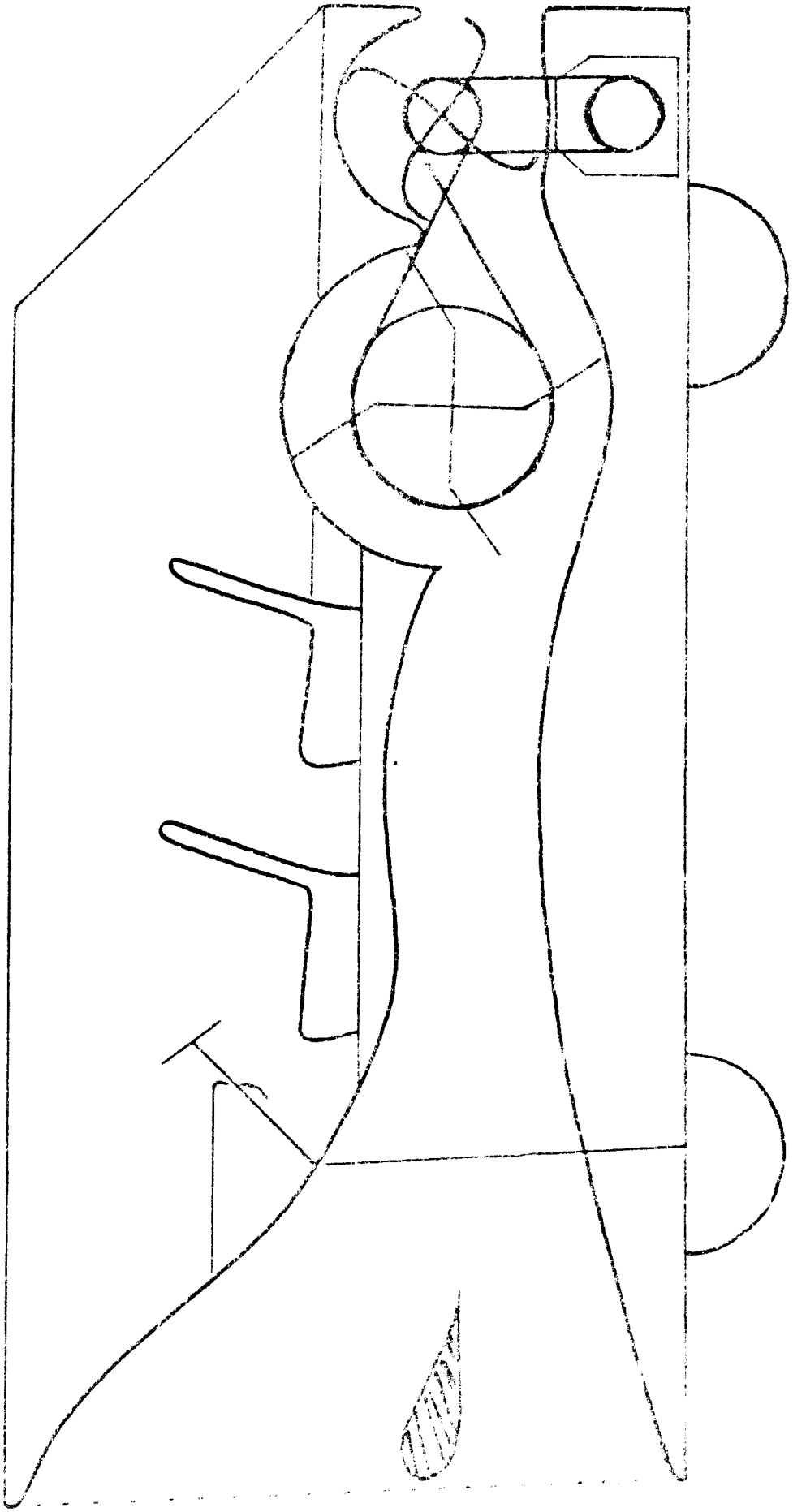
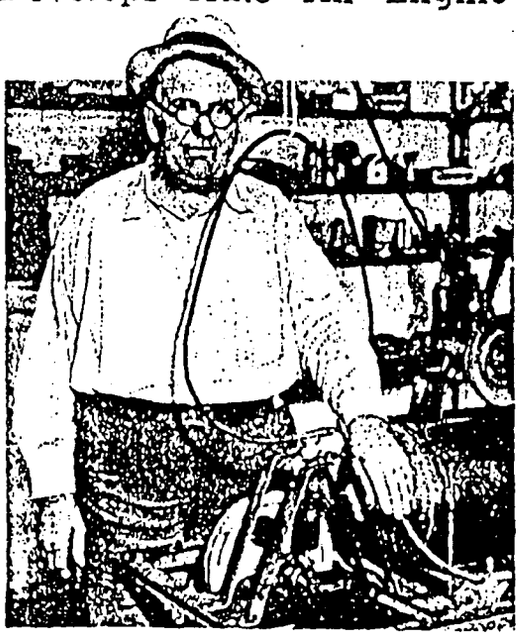
123

DESIGN NINE



Develops Auto Air Engine



Visualizing autos powered with compressed air motors, Charles Hunt, Springfield, Mo., inventor, built this model motor to prove theories. Tank at right stores compressed air supply.

ACTUATED by the rocking and swinging of a moving auto, pumps attached to the auto's shock absorbers compress air in tanks and supply power for turning crankshaft of a model automobile engine developed by Charles Hunt, 67-year-old inventor of Springfield, Mo. Two reserve air tanks, fillable at service stations, are part of the engine's equipment.

Modern Mechanix